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CONSEIL PERMANENT INTERNATIONAL
POUR L'EXPLORATION DE LA MER
CHARLOTTENLUND SLOT – DANEMARK

JOURNAL DU CONSEIL

VOL. XI · NO. 3

PUBLIÉ PAR LE BUREAU DU CONSEIL

RÉDIGÉ PAR

E. S. RUSSELL

EN COMMISSION CHEZ
ANDR. FRED. HØST & FILS
COPENHAGUE

DÉCEMBRE 1936

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IMPRIMERIE A/S L. IHRICH

On the Relationship between Dynamic Topography and Direction of Current under the Influence of External (Climatic) Factors.

By

A. E. Parr.

Bingham Oceanographic Laboratory, Yale University.

IN spite of all the pertinent reservations and restrictions made in the abstract deduction of the modern hydrodynamic equations, it is commonly stated that the dynamic contour lines can to all practical purposes be regarded as representative of true lines of flow, and this has become an almost universally adopted rule in the practical application of hydrodynamic methods (even, one may find, to waters in contact with sloping bottoms and other topographical complications which shall not concern us here). In the course of certain marine investigations of which he has recently been in charge, the writer has been considerably troubled with the difficulty of reconciling, except in the grossest general features, the picture of ocean currents obtained from this "practical" interpretation of dynamic topography with other hydrographic evidence bearing upon the transportation of water masses. Outstanding examples of such discrepancies are those cases in which dynamic contour lines take their departure from solid land in regions in which no upwelling can occur. A practical method of evaluating dynamic topography in terms of actual directions of flow is plainly needed, and under a certain very common and important set of conditions applying to the open ocean as well as to inshore waters it may not be impossible to devise such a method.

Let us assume that a body of water actually flows from a lower to a higher latitude on the northern hemisphere, as illustrated at the upper left in our Figure 1. In the course of this flow it becomes chilled, and other things remaining equal its surface therefore loses dynamic height. Dynamic contour lines would consequently have to be drawn at right angles to the actual lines of flow which had been followed. According to the current "practical" interpretation of dynamic topography this

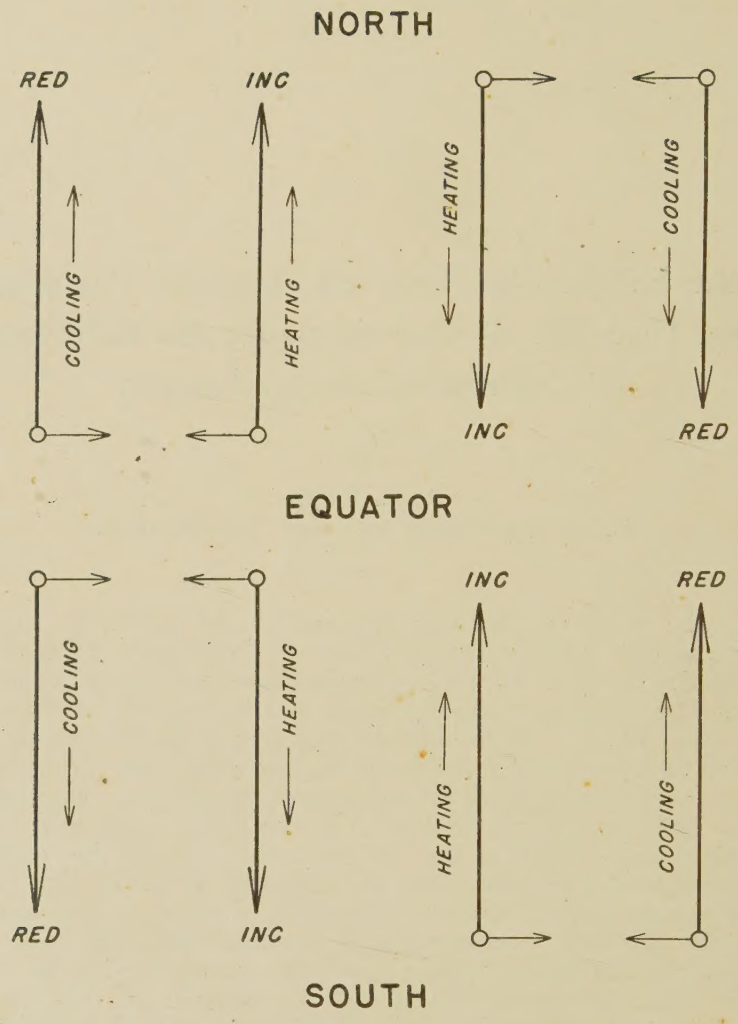

Figure 1.
Eight theoretical situations in which the apparent direction of flow (thin horizontal arrows) indicated by the customary interpretation of dynamic contour lines would be at right angles to actual direction of flow (thick vertical arrows) on both hemispheres. Dynamic height decreasing (r e d.) in the direction of cooling, increasing (i n c.) in the direction of heating.

would then be taken to mean that the water could only have flowed at an angle of 90° to the actual course of the current, in the direction indicated by the finer horizontal arrow.

This introduces the principle that whenever dynamic heights in the direction of a current's flow are changed by the influence of external non-kinematic forces (heating, cooling, condensation, dilution etc.) the

current must have a component at 90° to the direction of the dynamic contour lines. It is also immediately apparent from an inspection of the other cases illustrated in our Figure 1 that when dynamic height is thus reduced in the direction of flow the actual current will deviate to the left from the dynamic contour lines and when dynamic height is increased the current will deviate to the right on the northern hemisphere; with the inverse relationships obtaining south of the equator.

Regions of different external influence will, in other words, create a field of energy in the intervening area tending to cause the dynamic contour lines to pass at right angles to a line between such opposite regions. If this field of external energy is not opposed by internal energies in the ocean both the dynamic contour lines and the actual lines of flow must ultimately take this direction at right angles to the gradient of external influence. This principle has the important implication that when dynamic contour lines do *not* run at right angles between the centres of different external influences, but have a component in the direction from one to the other, this in itself is evidence that the actual lines of flow are neither determined by external nor by internal forces alone, but by an interaction between the two, and must therefore deviate from the dynamic contour lines in the manner stated in our first thesis. To establish the actual lines of flow it is therefore necessary to take both internal and external fields of energy into consideration.

In our Figure 2 the external field of energy is represented by the parallels EXT. 1 — EXT. 3, the internal field by parallels INT. 1 — INT. 4, both expressed in the same units in terms of the topographic gradient of the isobaric surface under consideration which either field of energy would produce independently in the absence of the other, but with the abstract assumption of the continued flow of the same current; the contour lines being numbered in sequence from lower to higher dynamic levels. Under the conditions illustrated, the internal field of energy would obviously contribute the current component A→B to the flow of water from point A, the external field contributing the component A→E. None of the restrictions attached to the use of the hydrodynamic equations would apply to a determination of the separate components by this method. The resultant actual flow from point A is consequently indicated by the arrow from A to C. But in flowing from A to C the waters of the current suffer a total cumulative loss within themselves of 1 unit dynamic height under the influence of the external field of energy (e.g., by chilling). At point C the surface of the current consequently has an actual dynamic height one unit lower than the topographic height of the intercept between EXT. 2 and INT. 2 at point A, or equal to the height of the intercept between EXT. 2 and INT. 1. The actual, that is, the observed dynamic contours consequently run from the latter point to C and correspondingly from A to D, and so on, as shown by the lines: OBS. 1 — OBS. 7.

For accurate determination of the actual lines of flow a knowledge

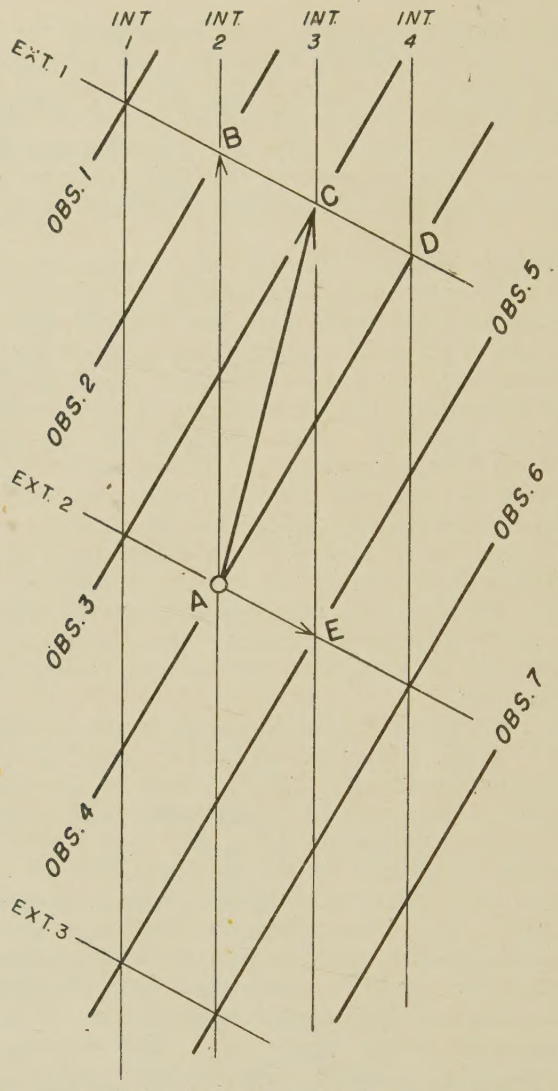

Figure 2.
Relationship between internal and external fields of energy, actual direction of current and observed dynamic topography.

of at least two of the following three sets of data is required: 1) The actual topography, and 2) the topography of the internal field of energy alone, or 3) the nature of the external field of energy in terms of its direct influence upon the dynamic topography of the region considered. The actual topography is derived directly from observations, and is usually presented as a matter of oceanographic routine. To plot approximately the external field of energy in terms of its influence upon the actual topography does not seem beyond possibility[1]).

[1]) In a plot of this sort one would have to take into account the actual character of the waters in the region investigated with reference to the rate at which their densities would be changed under the influence of the external forces.

An interesting aspect of the external field would be the seasonal change of its gradient of influence. The available data for plotting in two dimensions the (influence of) the external field are probably still inadequate for most oceanic regions, but a practical method for determining approximately the true lines of flow from data given in one dimension only may be derived from the following considerations.

Given an actual topography determined directly from observations, such as that indicated by the contour lines OBS. 1 — OBS. 7 in our Figure 2 we may attempt to determine (e.g., from observed temperature differences for equal or corresponding salinities in waters of traceable identity) the total loss of dynamic height which would occur due to the influence of external forces (mainly chilling, but also condensation or dilution) alone if the waters had really moved along an actual contour line from A to D. Finding that approximately one unit dynamic height would have been lost in this manner over the distance considered, we know that a body of water flowing from an actual topographic level of OBS. 4 at point A must have reached topographic contour line OBS. 3 at a point C corresponding to point D on OBS. 4 or conversely that at body of water arriving at D must have departed from actual topographic contour line OBS. 5, at a point E corresponding to a point A on OBS. 4. In practice one should be mainly guided by the version of the above method which gives the least distance between established points on the actual contour line along which the calculations are made and the "corresponding" points on other contour lines, which must be fixed by personal judgement only, in the absence of precise knowledge of the gradient of external influence. With actual contour lines converging in the direction of flow, the first version, extrapolating from D to C should therefore be given main attention, the second version when contour lines diverge, but the best result would probably as a rule be obtained by a comparison of opposite versions for next adjacent actual contour line. With these precautions the personal judgement will probably as a rule not be greatly in error, and will certainly give us a much more nearly true picture of actual direction of flow than that obtained from the actual topographic contour lines.

In regard to a method for ultimate determination of the entire field of influence of external factors, we may suggest that the loss in dynamic height which we estimate would have occurred along an actual dynamic contour line (OBS. 1 — OBS. 7, in Figure 2) according to observed differences of external origin be designated as the dynamic discrepancy. If, starting from one extreme area of external influence, we estimate the dynamic discrepancies along the different contour lines of the actual topography at a sufficient number of points, we can draw the curves of equal dynamic discrepancies, and these would directly represent the contour lines of the field of influence of the external forces (N.B. *not* the field of external energy itself) determined from hydrographic observations alone. The actual lines of flow would then run diagonally between the intercepts of these contour lines (EXT. 1 — EXT. 3) and the contour lines of actual topography (OBS. 1 —

OBS. 7, see Figure 2). To apply this method with great precision would be very difficult, but to do it in sufficient approximation for general guidance in the interpretation of dynamic topography in terms of actual lines of flow seems quite feasible. The writer shall not go to the extent of attempting an actual application of this entire procedure in this short article, but shall merely endeavour to show in the following the importance of giving consideration to the principles here developed by taking a well-known example from the literature as a rough illustration.

If we take the dynamic topography of the North Atlantic as presented by Jacobsen[1]) according to standard oceanographic methods, and begin with the assumption that the dynamic contour lines also represent actual lines of flow, we may follow in our imagination the movement of a cube of surface water a hundred metres deep, wide, and long from the Florida Current south of Cape Hatteras along the line of 0 relative dynamic height to its extreme north-eastern point, north-west of the Iberian peninsula. If we now compare its characteristics at the time it left the Florida waters with its features when it arrives at the extreme north-eastern point[2]) we find that it will, on the annual average, have suffered a reduction in surface temperature from about 25° C. to 15° C. or less, with the surface salinity remaining almost unchanged (about 35·5 ‰), which gives a reduction in (anomaly of) specific volume at the surface of about 250×10^{-5}. Since the changes at 100 metres depth, while not identical with those at the surface, have probably been of about the same magnitude with reference to density, we may, for the sake of this rough illustration, assume the loss of specific volume at the surface to be representative of the entire 100 metre thickness of our cube, which has thus within itself alone suffered a loss of dynamic height in passage of no less than 25 dynamic cm. or one-third of the total dynamic slope throughout the entire North Atlantic current-system. Other things being equal, the actual path of our cube of surface water should therefore have been crossed by no less than 5 such dynamic contour lines as those shown in Jacobsen's chart. In other words, to arrive at the extreme north-eastern end of the 0 dynamic contour line our cube of water must have started from about 25 cm. relative dynamic height in the region south of Cape Hatteras; or, if it started from 0 dynamic height, it must arrive proportionately farther to the north-east than indicated by the 0 dynamic contour. That is, the actual line of flow from 25 cm. relative dynamic height south of Cape Hatteras must extend approximately to the extreme point reached by the 0 contour line (or beyond), and the line of flow from 0 height in the south-west

[1]) J. P. Jacobsen: Contribution to the Hydrography of the North Atlantic. Danish "Dana" Exp. 1920—22. Oceanogr. Rep. No. 3. Copenhagen, 1929, Fig. 53.

[2]) Since this is merely meant as a very rough illustration, the writer has considered it adequate for our present purposes to take his information from the charts of surface salinities and average annual surface temperatures published by G. Schott in his *Geographie des Atlantischen Ozeans.* Hamburg, 1926 (Plates VIII and X).

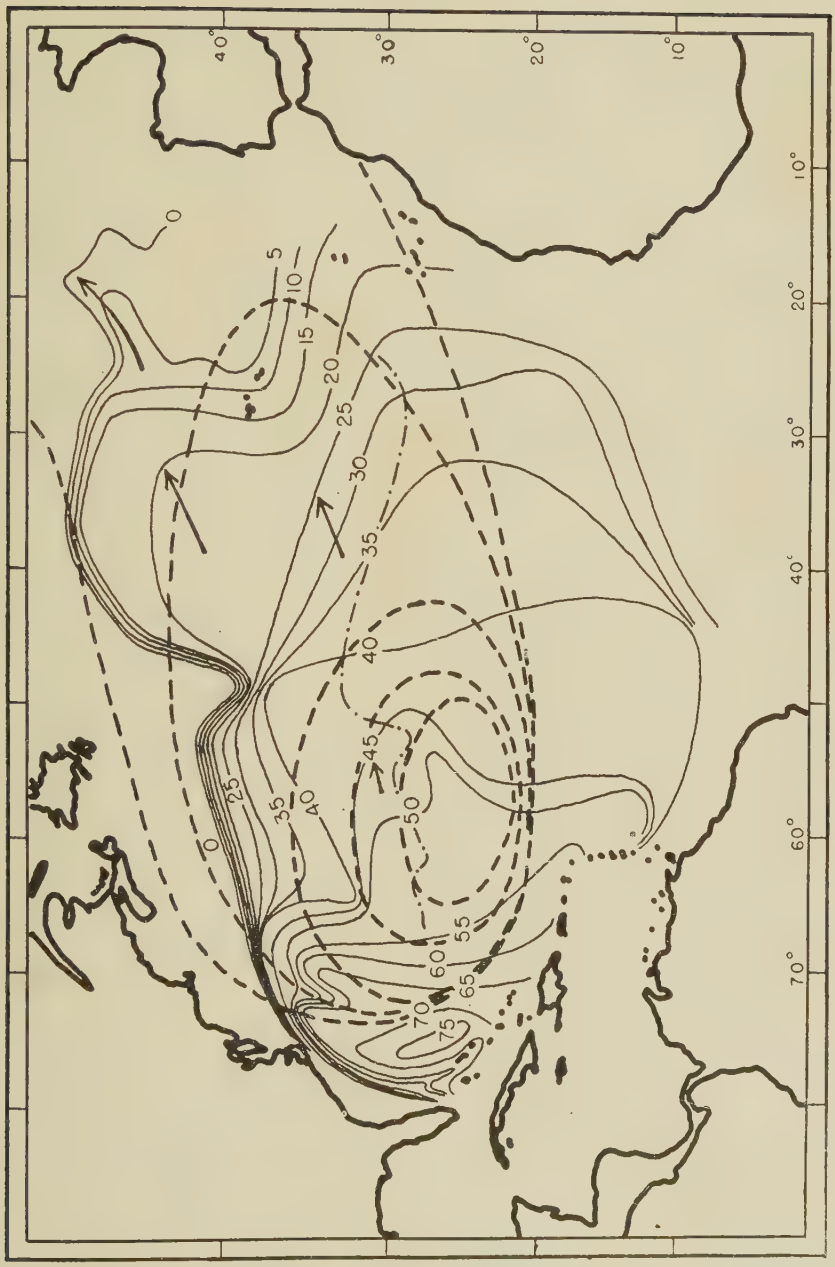

Figure 3.
Dynamic topography of the North Atlantic according to Jacobsen (solid contour lines) with distribution of successive stages of eel larvae according to Schmidt (broken lines), probable actual directions of flow (arrows) suggested according to methods herein developed, and northern subtropical convergence according to Meyer (dot and dash).

must extend proportionately farther to the north-east. Similar evaluations of dynamic discrepancies at the locations on the contour lines for 20, 25, and 45 cm. relative actual height towards which our arrows in Figure 3 are pointing give values of about 20, 15 and 13 cm. In accordance with the principles here developed, applied to these approximate evaluations, arrows have been entered in our figure to indicate general actual direction of flow. It is evidently utterly impossible that a cube of water could have followed any single dynamic contour line at any level to which the effect of external factors may penetrate, since the same reasoning would apply to any particular case we might choose to consider.

For corroborative evidence we may now again turn to the literature. In Figure 3 we first compare the distribution of successive stages of larval European eels, according to Schmidt[1]), with the dynamic topography of the North Atlantic according to Jacobsen. This comparison has already previously been used in confirmation of the standard interprétation of dynamic contour lines as approximate actual lines of flow. But a closer scrutiny will immediately reveal that the comparison on this basis really offers great obstacles in its details, and it will also be seen that these obstacles would be entirely removed and a very much better fit would be obtained if the lines of actual flow were dispersed much farther in a north-easterly direction, as suggested by the arrows entered according to the principles here introduced.

For final and conclusive proof of the justification of our methods, we will now compare the general directions and location of our arrows with the current chart prepared by Meyer[2]) from actual observations of the drift of ships etc. To facilitate the comparison the northern subtropical convergence has been entered (dot and dash) in our figure as a line of reference; and a comparison discloses a perfect agreement in general terms between our interpretation of dynamic topography and actually observed directions of flow, where an enormous discrepancy would exist if the "practical" rule of regarding the topographic contour lines as approximate actual lines of flow were applied in this case.

Fully aware that this is not a finished mathematical treatment of the problem, and it is not intended as such, the writer is hopeful that these simple considerations and principles may serve to extract in general terms from the dynamic topography of the upper isobaric levels some really helpful information to correlate with the problems of biological distribution and the horizontal distribution of water masses, where topographic information under current practical rules seems to offer mainly obstacles.

It is evident, of course, that the influence of the external field (mainly represented by heating and cooling) on the dynamic contour

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[1]) Johs. Schmidt: Danish Eel Investigations during 25 years. Copenhagen, 1933. Publ. by the Carlsberg Foundation. And earlier papers by the same author.

[2]) H. F. Meyer: Wasserbewegung a. d. Oberfläche im Februar. Fig. 51 opposite p. 528 in Zeitschr. Gesell. f. Erdkunde, Berlin. Sonderband 1928.

lines will rapidly diminish from the surface downwards. In our example from the North Atlantic current-system we have simply assumed that the drop in temperature throughout the upper 100 metres along the 0 contour line has been solely due to external chilling alone. This will probably be very nearly, but not entirely, true. On the other hand, the error of the assumption will perhaps be more than compensated for by the fact that the influence of external factors will undoubtedly in some degree penetrate deeper than the upper 100 metres. On the whole it will therefore be fair to assume that the discrepancy equivalent of 25 dynamic cm. may approximately represent the total cumulative discrepancy equivalent from surface to bottom along the area of that path of the North Atlantic current-system which we have here considered.

It is obvious from the apparent magnitude of this discrepancy that a formula for evaluating dynamic topography in terms of actual lines of flow is absolutely essential.

On the Probable Relationship Between Vertical Stability and Lateral Mixing Processes.

By

A. E. Parr,

Bingham Oceanographic Laboratory, Yale University.

IN a separate paper the writer has had opportunity to report on a series of hydrographic observations in the Caribbean Sea (Parr 1936). Although they do not warrant designation as evidence on this point, some of the data forming the basis of that report do at least suggest the possibility, among others, that lateral mixing between adjacent "streaks" of current may be least extensive in the layers of least vertical stability. The writer has consequently become interested in the problem of the theoretical relationship between lateral mixing and vertical stability.

If we assume that the components of turbulent energy perpendicular upon the axis of the current are equally distributed in all directions the end points of potential turbulent movements in a homogeneous body of water would form a perfect circle. With vertical stratification in point of density the vertical components of motion produced by an equal force would obviously be reduced, while the horizontal components should *ceteris paribus* remain unaltered, and the end points of turbulent movements around the axis of flow might be expected to form an ellipse with a horizontal long axis of the same length as the diameter of our circle. Up to this point our conclusions have already been taken into consideration in meteorology by Taylor (1917, 1927, 1931).

But from actual observations in the lower atmosphere, Taylor has come to the conclusion that "all three components are reduced equally" so that the sphere of turbulence "is merely reduced in radius when a stabilizing density gradient exists" and "is not altered into an ellipsoid" (Taylor 1931, *loc. cit.*, p. 42). These observations and

conclusions of Taylor's, however, refer only to atmospheric eddy movements of a relatively low order of magnitude with a frequency of change often to be reckoned in numbers of fluctuations per minute. But when we are dealing with mixing processes in large volume between adjacent water masses we are also, and perhaps even mainly, concerned with a larger pattern of eddy motion on a much higher order of magnitude, which in Taylor's observations would correspond to the changes in the *mean* wind over periods of hours (or perhaps even days) whereas Taylor's conclusions refer only to the singularities of wind variations of high frequency and correspondingly low order of magnitude.

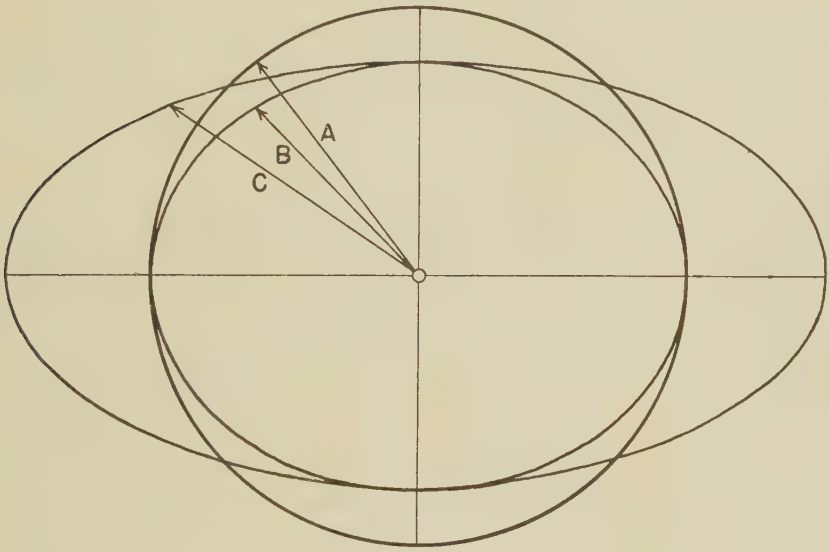

Figure 1.
Probable change of circular boundary of turbulent motion in a homogeneous fluid to an elliptic boundary with horizontal axis longer than the diameter of the circle in a vertically stratified fluid.

But in this turbulence pattern of higher order with which we are concerned in lateral oceanic mixing processes we are dealing with the irregular movements, as single units (only gradually disintegrating), of large bodies of water to be reckoned in cubic metres, decametres, hectometres or perhaps even cubic kilometres. And for the horizontal movements of such bodies of water we may carry our conclusions in regard to the probable distortion the circle of turbulent motion to an ellipsoid under conditions of vertical stability one step further *since it is evident that the reduction of the vertical components of turbulence (of all orders of magnitude) caused by this vertical stability also*

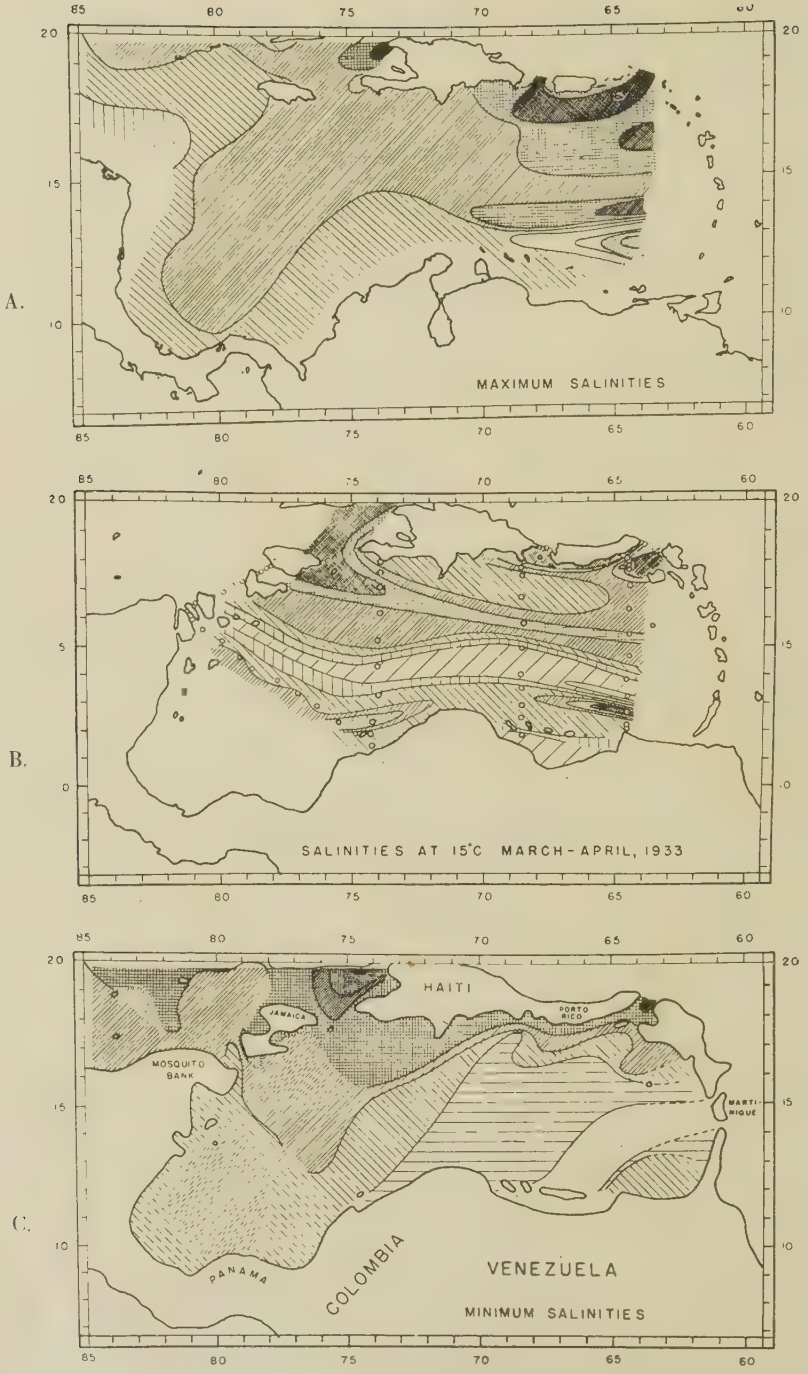

Figure 2. (For legends see p. 311, bottom).

reduces the vertical transfer of momentum or, in other words, the frictional resistance to the horizontal movements in the eddy patterns of higher orders of magnitude. The horizontal components of actual motion resulting from an equal force in the larger eddy patterns should thus not only be expected to remain unaltered but to be positively increased by vertical stability. Our circle of turbulent movements in an homogeneous fluid will not only be distorted to an ellipsoid with horizontal axis equal to the diameter of the circle, but with a much longer horizontal axis. The three steps in our deductions are diagrammatically illustrated in our Figure 1, the arrows A, B, and C representing singularities of movement resulting from the identical force according to each deductive step.

From these considerations we arrive at the principle that *vertical stability, while reducing the vertical mixing processes which are only of relatively very low orders of magnitude must also increase lateral mixing along isopycnal surfaces on a tremendously much larger scale in the horizontal eddy patterns of higher orders of magnitude.* Considering the cumulative effect of eddy patterns of all orders of magnitude involved in oceanic mixing processes it is thus evident that vertical and lateral stability must be in inverse relationship to each other. From these abstract considerations we may now turn our attentions to an actual set of observations from the Caribbean region which apparently provides an illustration and confirmation of our conclusions.

The waters of the Caribbean must obviously enter as many separate streaks of current through the various passages in the chain of the Lesser Antillean Islands in the east. Figure 2 shows the persistence or disappearance of these separate streaks in so far as they can be traced by their salinities. It would seem from these observations as though the streakiness of the layer of a temperature of 15° C., in spite of its relatively slight salinity differences, is much more stable and persistent than the streakiness of the maximum salinity layer above, *as well as* that of the minimum salinity layer below. While the streakiness of the latter two would seem to have disappeared at about 70° W. longitude by admixture into a general gradient from north to south, the streakiness of the former remains and extends itself much farther to the westward. A glance at the typical T-S correlation curve for this region (Figure 3) immediately reveals that the layer of 15° C. temperature, which shows such apparent horizontal stability, occupies

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A: Distribution of maximum salinities (about 100—150 metres depth). Contour lines for every 0·1 ‰ salinity from 36·5 ‰ (lightest shading) to above 36·9 ‰ (darkest shading).

B: Distribution of salinities in 15° C. isothermal sheet (about 200—400 metres depth). Contour lines for every 0·025 ‰ salinity from less than 35·90 (lightest shading) to more than 36·00 ‰ (darkest shading).

C: Distribution of minimum salinities (about 600—900 metres depth). Contour lines for every 0·05 ‰ salinity from 35·65 ‰ (dotted area 35·65—35·70 ‰) to 36·00 ‰ (darkest shading).

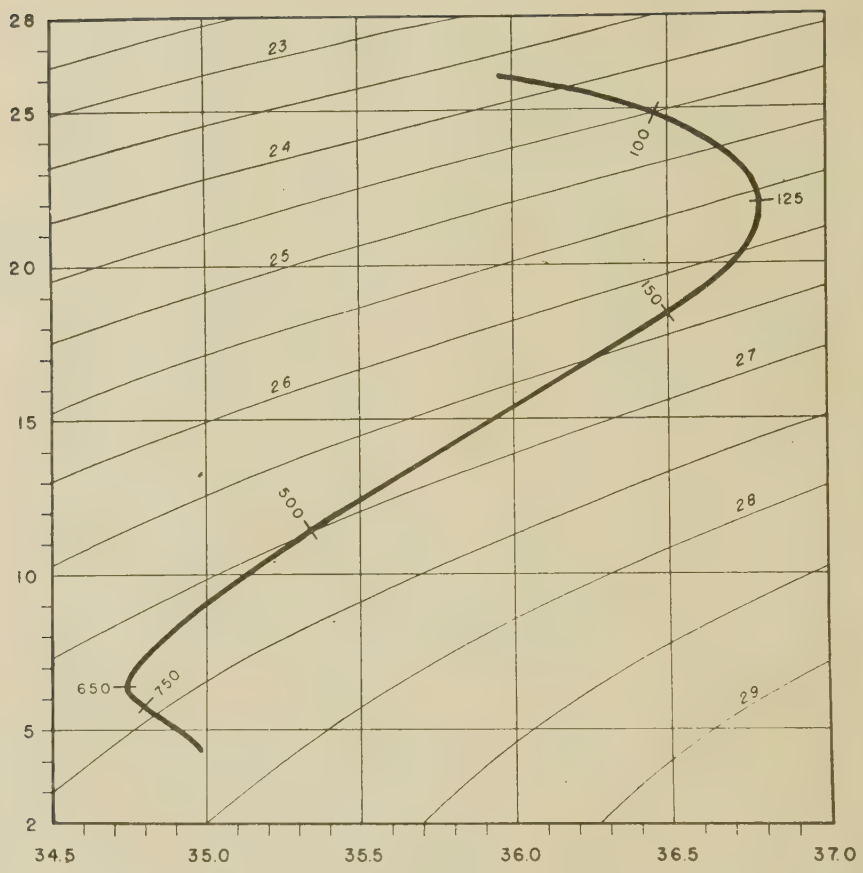

Figure 3.
Average Temperature-Salinity correlation curve for eastern Caribbean. Salinity scale in ‰ at bottom, temperature scale in ° C. at left, oblique isopycnals, and selected approximate average depths in metres marked along the curve.

the centre of the vertically most instable portion of the curve; while the horizontally instable maximum and minimum salinity layers each represent a maximum of vertical stability. The writer is, of course, fully aware that the principle here suggested is, under any circumstance, only one of several causes contributing to the situation shown in our figures, which is the reason why these data cannot be classified as evidence, but they do at least strongly suggest the presence of this factor among the others.

In any event, the logics of its derivation are so simple and obvious, and the observational data, such as they are, so suggestive of its validity, that the writer does not hesitate to assert his belief in the principle that vertical stability must promote lateral mixing, and *vice versa*, and to urge further investigation of this very important question.

An excellent opportunity for such an investigation would seem to be found in the eastern Caribbean and plans to secure a more detailed set of observations for this purpose in the near future are now under consideration.

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Zum Kalkgehalt der Ostsee.

Ergebnisse der ozeanographischen Untersuchungen des Fischerei-Instituts der Universität Königsberg Pr. im Jahre 1935—36 in der mittleren Ostsee. I.

Von

Andres von Brandt.

DIE hydrographischen Arbeiten in der Ostsee erstrecken sich in erster Linie auf die Erforschung einzelner Becken und deren physikalisch/chemischen Veränderungen im Laufe der einzelnen Jahre durch vierteljährige oder nur einmalige Untersuchungen in mehr oder weniger grossen Zeitabständen. Monatliche regelmässige Bereisungen grösserer Abschnitte der Ostsee liegen nur von finnischer (Granqvist, Jurva und Stenij, 1928 bis 1931) und lettischer Seite (Ozolins, Strand und Zarins, 1924 bis 1934) vor. Derartige mehrmalige Untersuchungen innerhalb eines Jahres lassen sich nur mit Hilfe planmässiger Dampferlinien ausführen. Die finnischen und lettischen Untersuchungsstrecken zogen sich vorwiegend an der schwedischen Seite der Ostsee hin (Dampferlinie Helsinki—Kopenhagen und Riga—Helsingborg, gelegentlich auch Riga—Kiel, 1926).

Im Sommer des Jahres 1935 wurden regelmässige Untersuchungen vor der deutschen Küste mit Hilfe des "Seedienstes Ostpreussen" auf der Strecke Pillau—Travemünde begonnen. Zur gleichen Zeit erfolgten mit Hilfe des "Finnlanddienstes" Untersuchungen auf der Strecke Pillau—Helsinki, so dass in der mittleren Ostsee auf der Strecke Travemünde—Pillau—Helsinki innerhalb weniger Tage erzielte Werte vorgelegt werden können (vergl. Karte).

Die Untersuchungsfahrten des Jahres 1935 lagen in den Monaten Juni bis Oktober und zwar an folgenden Daten:

vor der deutschen Küste:	*Finnlandstrecke:*
1) 13. Juni—16. Juni[a)]	12. Juni—17. Juni
2) 3. Juli—6. Juli	3. Juli—8. Juli
3) 20. Juli—25. Juli[b)]	24. Juli—29. Juli
4) —	7. August—12. August
5) 4. Sept.—5. Sept.[c)]	4. Sept.—9. Sept.
6) 23. Okt.—24. Okt.[d)]	—

[a)] nur bis Swinemünde und zurück, [b)] ausser der Strecke Pillau—Travemünde und zurück die Strecke Pillau—Memel und zurück, [c)] Untersuchung nur auf einer Strecke: Pillau—Zoppot—Binz—Warnemünde—Travemünde, [d)] Untersuchung nur auf einer Strecke: Kiel—Swinemünde—Zoppot—Pillau.

Im Jahre 1936 erfolgten zwei ergänzende Fahrten vor der deutschen Küste zwischen Pillau und Swinemünde und zwar am

7) 26. März—28. März
8) 27. April—30. April.

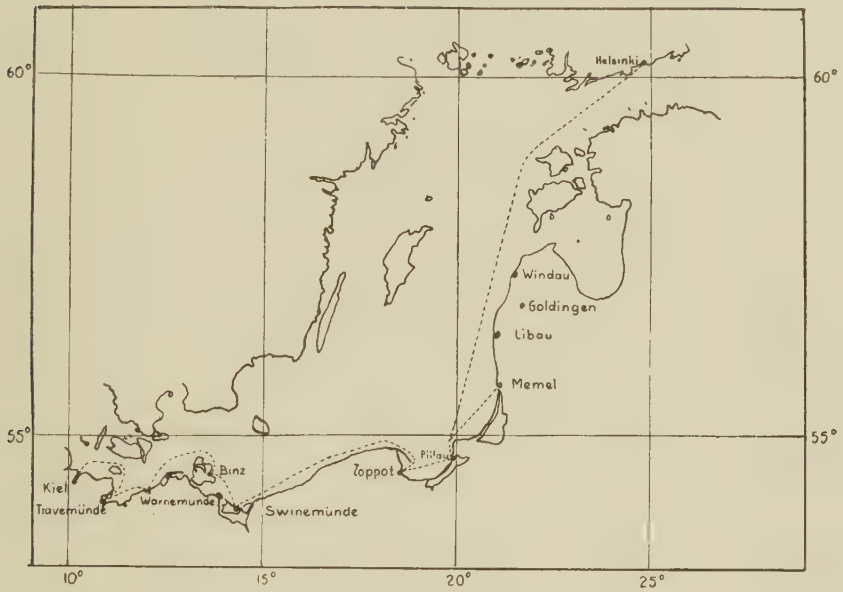

Abb. 1. Untersuchungsstrecken.

Die Benutzung der regelmässig verkehrenden Dampfer gestattet nur eine Probeentnahme von der Oberfläche. Die Entnahme erfolgte mit dem Wasserschöpfer nach S u n d[1]) (1931) oder mit Messingschöpfern von dem gleichen Durchmesser aber ohne Thermometereinsatz. Die Entnahme vom fahrenden Schiff mit diesen gut vertauten Röhren bereitete nicht die geringsten Schwierigkeiten, auch nicht bei starker See.

Da bei den finnischen und lettischen Untersuchungen mit Tourendampfern die Wasserproben von ungeschultem Personal entnommen wurden, konnte nur die Temperatur und später im Laboratorium der Salzgehalt bestimmt werden. Die Untersuchungen des Fischerei-Instituts der Universität wurden von cand. rer. nat. H. P i l w a t und dem Verfasser ausgeführt, so dass, soweit notwendig, die Analysen bereits an Bord eingeleitet werden konnten.

Der Zweck der Untersuchung war, ein Bild von den hydrographischen Verhältnissen des Oberflächenwassers der mittleren Ostsee durch Messungen an den verschiedensten Punkten innerhalb kurzer Zeit zu gewinnen. Damit soll ein Aufschluss gegeben werden über die

[1]) Der Wasserschöpfer wurde dankenswerterweise von der Deutschen Seewarte in Hamburg zur Verfügung gestellt.

Zustände wichtiger Faktoren in einem Gebiete, das, soweit dies nach dem heutigen Stande der Erforschung der Lachswanderung bekannt ist, von diesem Fisch durchwandert wird (Quednau, 1932, Alm, 1934). Da die Veränderungen der biologischen Faktoren des Ostseewassers nicht allein auslösend oder bestimmend für Zeit und Weg der Lachswanderungen sein dürften, ist die Mitwirkung der hydrographischen Faktoren auf direktem und indirektem Wege anzunehmen[1]). Gerade für das Ostseegebiet sind zahlreiche Beispiele der Verquickung von biologischen und physikalisch/chemischen Vorgängen bekannt. Durch die Salzwassereinbrüche der Nordsee in die westliche und mittlere Ostsee wird es zahlreichen Tieren möglich, aus der Nordsee in die Ostsee einzuwandern. Alm (1934) nimmt für die die Lachswanderung bestimmenden Faktoren neben Nahrungsfragen Temperatur und Salzgehalt an. Lundbeck (1928) berichtet über Zusammenhänge der Lachsfangplätze und der Hydrographie des Wassers; so werden von den Fischern mehrere Wasserarten unterschieden, z.B. "schwarzes Wassér", d.h. klares salzreiches Wasser der hohen See und "weisses Wasser", d.h. stark getrübtes Süsswasser aus den Flussmündungen. Willer (1933) weist darauf hin, dass der grosse Stint bei seiner Rückwanderung aus der Ostsee in das Kurische Haff zu seinen Laichplätzen den schwachen eingehenden Salzwasserströmen folgt. Für die Sprottenwanderung konnte Borowik (1924) den Zusammenhang mit der Wasserführung der Weichsel und dem Salzgehalt der Danziger Bucht nachweisen. Demel (1928) zeigt den Zusammenhang von Windströmungen, die kaltes, salzreiches Tiefenwasser der Danziger Bucht an die Oberfläche bringen, mit den wechselnden Fischbeständen.

Die Beispiele des Zusammenhangs von Fischwanderung und Hydrographie lassen sich noch vermehren, es sind hier nur einige markante Beispiele vor der deutschen Küste wiedergegeben. Vor der japanischen Küste gelang es sogar Uda und Okamato (1936) Formeln aufzustellen, die es erlauben, aus der Temperatur den ersten Sardinen-Fangtag mit ziemlicher Sicherheit zu berechnen.

Besonders für die Auffindung der Flussmündungen durch den Lachs, der aus wirtschaftlichen Gründen im Vordergrunde unseres Interesses steht, ist eine Indifferenz der hydrographischen Faktoren undenkbar (vergl. Seligo, 1926, Willer, 1934). Für diese noch laufenden Untersuchungen der für die Fischerei der pommerschen und ostpreussischen Küste so wichtigen Frage der Lachswanderung und der Auffindung der Flussmündungen sollen die vorliegenden Untersuchungen neben der Klärung allgemein interessierender Fragen der Hydrographie der Ostsee Grundlagen zur weiteren Arbeit geben.

Die beiden Untersuchungsstrecken vor der deutschen und vor der baltischen Küste unterscheiden sich zunächst durch die Entfernung

[1]) "Quoi qu'il en soit, nous sommes persuadés que la solution des questions de pêcheries touchant les problèmes de la biologie, de l'hydrologie et de la climatologie exige notre intense harmonieuse collaboration avec les géophysiciens et les hydrologistes." (Borowik, 1931).

von der Küste und die Wassertiefen, die passiert werden. Im Gegensatz zur Finnlandstrecke lag die Fahrtroute vor der deutschen Küste näher zum Lande. Bei der Überquerung der Danziger Bucht von Pillau nach Zoppot und um Hela wurden Gebiete mit grösserer Wassertiefe (bis 82 m.) passiert, sonst überschritten die Wassertiefen dieser Strecke selten 30 m. Nur bei der fünften Fahrt (4. und 5. September 35) wurden auf der direkten Strecke Pillau—Binz ohne Zwischenlandung in Swinemünde küstenfernere Gebiete mit Tiefen über 60 m. passiert. Auf der Finnlandstrecke dagegen handelt es sich vorwiegend um küstenfernere Ostseeteile mit Tiefen, die über 50 m. betragen, mit Ausnahme einiger Teile vor der litauischen Küste und kleinerer Bänke vor dem Rigaer Meerbusen, an der Westküste von Ösel, vor Dagö und vor Helsinki.

Es wurde eine möglichst umfangreiche Auswertung der auf den Untersuchungsfahrten gewonnenen Wasserproben erstrebt. Die abgeschlossenen Analysen beziehen sich auf Salzgehalt, Kalk, anorganische Phosphate, Gesamtphosphor, Silikate, NO_3-Stickstoff und NH_4-Stickstoff des Oberflächenwassers (v. Brandt, 1936). Von diesen soll im folgenden über die Ergebnisse der Kalkgehalts- und Salzgehalts-Bestimmungen berichtet werden.

Der Kalkgehalt der mittleren Ostsee vor der deutschen und baltischen Küste.

Dem Kalkgehalt der Meere wurde in neuerer Zeit stärkere Beachtung geschenkt, da er bei den Untersuchungen über die Kohlensäureverhältnisse und bei biologischen und geologischen Fragestellungen von Wichtigkeit ist.

Im Gegensatz zum Ozean, über dessen Kalkgehalt zahlreiche Untersuchungen vorliegen (z. B. Wattenberg, 1930, ders. 1933, ders. u. Timmermann, 1936), sind die Angaben über den Kalkgehalt der Ostsee sehr spärlich oder nur für bestimmte Teile gültig. Zur Ausfüllung dieser Lücke sollen vorliegende Untersuchungen in der mittleren Ostsee, als dem wesentlichsten Teil dieses Gebietes, beitragen.

Angewandte Methode.

Da die Ca-Ausfällung bei Serienbestimmungen an Bord von Forschungsschiffen, erst recht aber an Bord der regelmässig verkehrenden Passagierdampfer und Frachter, mit grossen Schwierigkeiten verbunden ist, wurde bei den meisten bisherigen Untersuchungen von der Bestimmung der Gesamt-Ca-Konzentration abgesehen und die Erfassung der besonders biochemisch bedingten Differenzen der Ca-Konzentration auf indirektem Wege über die Alkalinitätsbestimmung (Wattenberg, 1930) vorgenommen. Demgegenüber wurde in den vorliegenden Untersuchungen in der mittleren Ostsee die direkte Bestimmung der Ca-Konzentration durchgeführt. Die Ca-Menge wurde aus dem zunächst mit Ammoniak, dann mit Essigsäure versetzten Seewasser mit

Ammoniumoxalat gefällt, filtriert und aus dem Kaliumpermanganat-Verbrauch des mit konzentrierter Schwefelsäure gelösten Niederschlages die vorhandene Ca-Menge errechnet. Die titrimetrische Bestimmung der ausgefällten Ca-Menge wurde der gewichtsanalytischen, wie sie Zarins und Ozolins (1935) verwandten, vorgezogen. Die Angabe der gefundenen Mengen erfolgte in Ca mg./l.

Die direkte Fällung der Ca-Ionen war deshalb möglich, weil die Bestimmung erst nach Beendigung jeder Fahrt im Laboratorium vorgenommen zu werden brauchte. Diese Bestimmung ist kaum umständlicher als die im kohlensäurefreien Luftstrom vorgenommene Titration des Basenüberschusses (vergl. Wattenberg, 1933). Ausschlaggebend für diese Fällungsmethode blieb aber die aus den Untersuchungen von Zarins und Ozolins (1935) hervorgehende Tatsache, dass die Alkalinitäts-Schwankungen in der vom Flusswasser stark beeinflussten Ostsee nicht identisch den jeweiligen Konzentrationsveränderungen der Ca-Ionen sind, wie sich aus den folgenden, der Arbeit der genannten Autoren entnommenen Beispielen der Oktoberwerte für das Oberflächenwasser an 6 Stationen vom Innern des Rigaer Meerbusens bis in die offene Ostsee in der Höhe von Gotland ergibt:

	Alkalinität	Ca mg./l.
Stat. 2	1·7410	83·1
„ 3	1·7276	80·9
„ 3a	1·7013	87·5
„ 4	1·5445	99·5
„ 4a	1·5705	98·1
„ 5	1·4920	96·2

Mit der Entfernung von der Küste, d.h. von durch Flusswasser besonders stark beeinflussten Gebieten, nimmt die Alkalinität ab aber der Gesamt-Ca-Gehalt zu. Mit der Bestimmung der Ca-Ionen werden nicht nur die an Kohlensäure gebundenen, sondern auch die der im Seewasser vorhandenen Ca-Salze starker Säuren erfasst. Der Anteil der durch die Alkalinitätsbestimmung erfassten Ca-Ionen schwankt mit dem Anteil des Flusswassers. Daher sagt in der Ostsee die Schwankung der Alkalinitätswerte nichts über die wirklichen Schwankungen der vorhandenen Ca-Ionen aus.

Herkunft der Ca-Ionen.

Das in die Ostsee einströmende Nordseewasser bringt bedeutende Kalkmengen mit sich. So beobachtete schon Forchhammer (1858) im ausgehenden Oberflächenstrom 161 Teile Kalk gegenüber 355 im eingehenden Tiefenstrom. Das salzreiche Wasser des Tiefenstroms wird zum grössten Teil mit dem Ostseewasser vermischt, ein kleiner Teil gelangt in die Mulden des Zentralbeckens. Das Ostseewasser stellt ein Gemisch des eingedrungenen ozeanischen Wassers mit dem der Flüsse dar. Der Einfluss des salzreichen Tiefenstromes nimmt von Westen nach Osten und Norden ab. Andererseits nimmt mit fortschreitender Entfernung von den Belten und Sunden, wie von den

Mulden zur Küste, der Einfluss des Flusswassers zu. Die Flüsse bringen grössere Kalkmengen mit sich. Diese sind innerhalb ein und desselben Flusses jahreszeitlich verschieden und bei den verschiedenen in die Ostsee einmündenden Flüssen abhängig von den geologischen Verhältnissen des durchflossenen Gebietes. So fliessen von den Urgesteinsgebieten Schwedens und Finnlands dem Bottnischen und Finnischen Meerbusen kalkarme Flüsse zu, während in den Finnischen Meerbusen von Süden kalkreiche Flüsse kommen. Ebenso sind die deutschen Flüsse relativ kalkreich. Der Ca-Gehalt des Flusswassers liegt aber stets unter dem des entsprechenden Mündungsgebietes der Ostsee, wie die Analysen aus den Flussmündungen ergeben.

Der das Flusswasser übersteigende Kalkgehalt der Ostsee hat seine wesentliche Quelle in dem Wassereinstrom aus der Nordsee. Für den Kalk müssen daher ähnliche Verhältnisse zutreffen wie für den Chloridgehalt. Mit abnehmenden Anteil des kalkreichen, ozeanischen Wassers sinkt der absolute Ca-Gehalt in der Ostsee wie der Chloridgehalt, jedoch, wie gezeigt werden wird, nicht im gleichen Verhältnis.

Das Endresultat ist eine regionale Verteilung des Kalkes, deren Staffelung aus den beigefügten Analysentabellen ersichtlich ist.

Ergebnisse der Untersuchungsfahrten.

Die Analysentabellen geben Auskunft über die Lage der Untersuchungsstellen, den Salzgehalt[1]), den Chloridgehalt, den Kalkgehalt und das Verhältnis Ca/Cl. Vorläufig sollen nur die Ergebnisse der Kalkbestimmungen besprochen werden.

Bei Ausschaltung der Proben aus den unter besonderen Bedingungen stehenden Mündungsgebieten der grossen Flüsse und der Häfen ergibt sich für die mittlere Ostsee ein ausgeprägtes Kalk-Gefälle, da der Kalkgehalt von Westen nach Osten und Norden abnimmt. Dieses Gefälle war durchaus auf Grund des in der Ostsee bekannten Chloridgefälles und des hiermit verbundenen konventionellen Salzgehaltes zu erwarten, da der durch die Sunde eingehende Tiefenstrom die Hauptquelle des Chlorid- und Kalk-Gehaltes ist.

Auf der ersten Untersuchungsreise (12.—17. VI. 1935) wurden keine Bestimmungen des Ca-Gehaltes vorgenommen, diese beginnen erst mit der Finnlandstrecke der zweiten Untersuchung vom 3.—8. Juli 1935. Auf der Hinreise (Pillau—Helsinki 3.—5. Juli) fanden sich auf der Strecke Brüsterort—Ösel Werte zwischen 114 und 100 mg./l. Ca. Auf der verhältnismässig kurzen Strecke von Ösel bis zum Beginn des Finnischen Meerbusens nahm der Ca-Gehalt weiter rasch auf 90 mg./l. ab, und innerhalb des Finnischen Meerbusens bis Helsinki gingen die Werte bis auf 80 mg./l. herunter. Auf der Rückreise (Helsinki—Pillau 6.—8. Juli) wurde ziemlich genau dieselbe Fahrtstrecke eingehalten, die

[1]) Der Salzgehalt wurde nach der Tabelle von Knudsen berechnet. Zarins und Ozolins haben im Zusammenhang mit Untersuchungen vor der lettischen Küste (1935) die Knudsen'sche Salzgehaltsformel für die Ostsee korrigiert, da sie aber nicht für die gesamte Ostsee gelten dürfte, ist bei diesen Untersuchungen an der Formel nach Knudsen festgehalten worden.

Werte für die Ca-Konzentration liegen aber, besonders vor der baltischen Küste, meist niedriger. Eine Quantität von 114 mg./l. wird nirgends erreicht, das Maximum ist 106 mg./l. Die Grenze zwischen Werten unter und über 100 mg./l. wird schon südlich von Ösel an der Einmündung des Rigaer Meerbusens erreicht. Die Werte unter 90 mg./l. beginnen nur wenig südlicher als auf der Hinreise am 5. Juli.

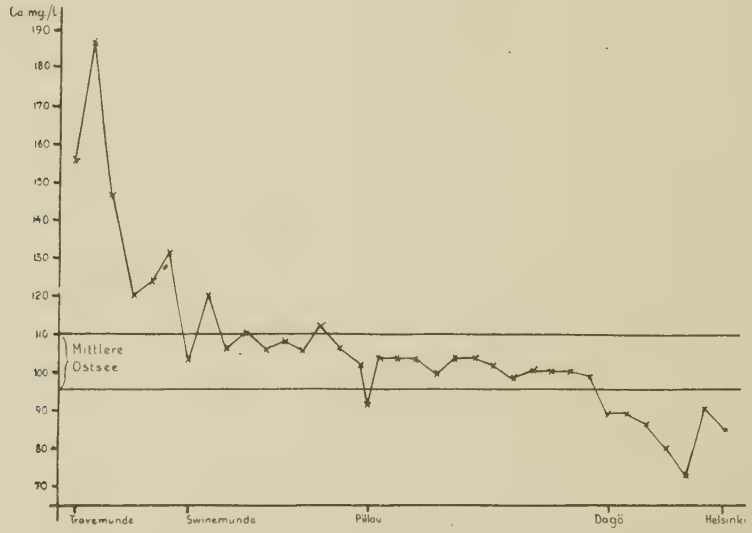

Abb. 2. Kalkgehalt in Ca mg./l. zwischen Travemünde und Helsinki am 23. bis 26. VII. 1935. Stationsabstände verschieden.

Die dritte Untersuchungsfahrt fand auf der Finnlandstrecke in der Zeit vom 24.—29. Juli 1935 statt. Auf der Hinreise 24.—26. Juli fanden sich zwischen der Danziger Bucht und Ösel ähnliche Werte wie am 6.—8. Juli. Die Abbildung 2 zeigt besonders deutlich die Einheitlichkeit der Werte zwischen Swinemünde und Dagö, während westlich bezw. östlich dieser Grenze sprungartige Veränderungen auftreten.

Der Abfall der Werte nach dem Passieren von Dagö unter 100 mg./l. ist nur noch stärker ausgeprägt, je weiter die Proben aus dem Innern des Finnischen Meerbusens stammen. Bis auf einige höher liegende Werte stimmen diejenigen der Rückfahrt (27.—29. Juli) gut mit denen der Hinfahrt überein. Die Wetterlage war besonders am 28. und 29. Juli sehr ungünstig (schwere See bei Windstärke 7/9). Die Ca-Konzentrationen vom 24.—29. Juli sind ähnlich denen auf der Rückreise der zweiten Untersuchungsfahrt am 6. bis 8. Juli 1935.

Es ist von Interesse, dass auf fast allen Reisen in der Höhe von Memel, und zwar bei 55°35′ bis 55°58′ N. und 20°08′ bis 20°14′ O., ein Wasser passiert wurde, das sich durch seinen hohen Kalkgehalt

auffällig von den übrigen Werten abhebt. Es kann sich nicht um Memelwasser handeln, das sich hier 60 bis 80 km. von der Küste bemerkbar machen könnte, da ebenso wie die norddeutschen Flüsse die Memel nicht über höhere Ca-Konzentrationen verfügt (vergl. Tab. V.) wie das Ostseegebiet, in welches sie einmündet. (In den Tabellen wurden diese Stellen mit Δ bezeichnet).

Während der dritten Untersuchungsreise wurde die Strecke vor der deutsche Küste über Pillau hinaus ostwärts bis nach Memel ausgedehnt. Die auf der Memelstrecke vor der Samlandsküste und der Kurischen Nehrung wie vor Memel gefundenen Werte geben keinen Hinweis, dass die obigen hohen Ca-Werte von der ostpreussischen Küste herstammen. Die hier gefundenen Werte schliessen sich an die vor der übrigen deutschen Küste gefundenen Werte an.

Die ersten Proben zur Kalkbestimmung vor der pommerschen Küste und in der Danziger Bucht wurden am 20. bis 24. Juli entnommen. Die Proben der Strecke Pillau—Travemünde (20. und 21. Juli) zeigen ein ziemliches Gleichbleiben der Ca-Konzentration bis vor Swinemünde. Im Zentralbecken der Ostsee herrscht auch beim Ca-Gehalt eine ziemliche Übereinstimmung von Ösel bis Swinemünde, soweit es sich um die hier untersuchten Oberflächenproben der angegebenen Strecke handelt. Wie von Ösel zum Finnischen Meerbusen ein rasches Abnehmen der Ca-Werte festgestellt werden konnte, so beginnt von Rügen zum Fehmarn-Belt ein ausserordentlich starkes Ansteigen des Ca-Gehaltes bis über 150 mg./l., analog den bekannten Chloridstaffelungen in der Ostsee (z.B. Schulz, 1929).

Die Rückreise am 23. und 24. Juli 1935 zeigt kaum eine Veränderung. Das Maximum des Ca-Gehaltes wurde auf der Rückreise mit 186 mg./l. bei 54°18′ N. und 11°47′ O. gefunden, welche Stelle auch den höchsten Salzgehalt während der dritten Untersuchungsfahrt aufwies. Auffällig ist, dass auf der Hinreise vor dem Molenkopf Swinemünde eine Menge von 98 mg./l., auf der Rückreise aber der hohe Wert von 132 mg./l. gefunden wurde. Starke Konzentrationsschwankungen im Ca-Gehalt sind allerdings im Gebiete von Rügen an der Odermündung zu erwarten, zumal eine Filtration des Untersuchungswassers zur Beseitigung eventuell schwebender Ca-Partikel nicht vorgenommen worden war.

Nach den Ergebnissen der zweiten und dritten Untersuchungsfahrt lässt sich sagen, dass ähnlich den Chloridgehaltsverhältnissen das grosse Zentralbecken der Ostsee, soweit von der Untersuchungsstrecke geschlossen werden darf, eine einheitliche Ca-Konzentration aufweist, die im Juli 1935 im wesentlichen zwischen 100 und 110 mg./l. Ca lag. Wie im Sommer ein Herabsinken des Salzgehaltes erfolgt, das gegen den Winter von erneuter Salzgehaltserhöhung abgelöst wird, so wird für den Ca-Gehalt, infolge der Gemeinsamkeit seiner wesentlichsten Quelle mit der des Chloridgehaltes, keine Konstanz seiner Konzentration im Jahreslauf erwartet werden dürfen.

Die vierte Untersuchung beschränkte sich wieder lediglich auf die Finnlandstrecke (7. bis 12. August). Die Ergebnisse von Hin- und

Rückreise sind einheitlich. Der Ca-Gehalt sinkt im Gegensatz zu den Juli-Ergebnissen nicht erst vor Ösel unter 100 mg./l., sondern bereits schon auf der Höhe zwischen Goldingen und Windau. Die Grenze am Beginn des Finnischen Meerbusens zwischen den Werten über 90 mg./l. und darunter ist ziemlich dieselbe geblieben. Das Konzentrationsbild dieser Reise zeigt das Maximum der Ausdehnung des kalkärmeren Wassers.

Die fünfte Untersuchung vom 4. bis 9. September 1935 erstreckte sich auf die Strecke vor der deutschen Küste wie auf die zwischen Pillau und Helsinki. Auf der Finnlandstrecke (Hinfahrt 4.—6. IX., Rückreise 7.—9. IX. 1935) ist bereits wieder eine Konzentrationssteigerung eingetreten. Die Untersuchung liegt einen Monat später als die vorhergehende. Mit ihr schliessen die Probeentnahmen auf dieser Strecke für 1935 ab, da es die letzte Reise des Ostpreussischen Finnlanddienstes in diesem Jahre war. Die Fahrtroute entspricht den früheren, wie überhaupt die Vergleichsmöglichkeit der Ergebnisse der verschiedenen Reisen ihre Berechtigung in der Übereinstimmung der Untersuchungsstrecken findet.

Die Ergebnisse der fünften Untersuchung weichen auf der Finnlandstrecke insofern von den früheren ab, als in der Höhe der Südspitze von Gotland (Kalkstein!) auf der Hin- und Rückfahrt höhere Werte auftreten, wodurch das Ca-Gefälle unterbrochen wird. Der Wert von 100 mg./l. Ca wird auf der Hin- und Rückfahrt in der Höhe der Südhalbinsel der Insel Ösel passiert, der Wert von 80 mg./l. zu Beginn des Finnischen Meerbusens. Das kalkreichere Wasser ist demnach wieder gegenüber den Augustwerten nach Norden vorgedrungen.

Vor der deutschen Küste wurden während der fünften Untersuchung Wasserproben nur auf der einen Fahrt von Pillau nach Travemünde am 4. und 5. September 1935 entnommen. Da eine Zwischenlandung in Swinemünde unterblieb, wurde auf dieser Fahrt tieferes Wasser passiert als auf den vorhergehenden. Leider musste die Untersuchung im August unterbleiben, so dass die Ergebnisse nur mit denen vom 20. bis 24. Juli verglichen werden können. Es lassen sich trotz abweichender Fahrtroute keine wesentlichen Differenzen feststellen. Die Werte um Rügen liegen etwas niedriger. Zwischen Warnemünde und Travemünde erscheint der höchste Wert, der bei dieser Untersuchung gefunden wurde, mit 178 mg./l. Ca. Es handelt sich hierbei anscheinend um Wasser, das aus dem Fehmarn-Belt kommt, in dem 1½ Monate später ein um 100 mg. grösserer Wert gefunden wurde.

Die letzte Untersuchung des Jahres 1935 bezog sich auf die Strecke Kiel—Pillau am 22. bis 24. Oktober, auf der vom Fehmarn-Belt an Wasserproben entnommen wurden. Im Fehmarn-Belt wurde entsprechend dem hohen Salzgehalt der Maximalwert von 279 mg./l. Ca angetroffen. Bis Rügen ist der Kalkgehalt bereits auf 120 mg./l. gesunken. Von der Höhe von Swinemünde an finden wir das übliche Bild der Gleichförmigkeit der Ca-Konzentration bis in die Danziger

Bucht. Verglichen mit den Werten der September-Untersuchung sind keine wesentlichen Unterschiede festzustellen. Da die Werte um Rügen etwas höher liegen, ist auch kein wesentlicher Gegensatz zu den Juliwerten zu finden.

Da auf der Strecke vor der deutschen Küste nur drei Fahrten während des Jahres 1935 vorgenommen worden waren, ergibt sich ein weniger übersichtliches Bild als auf der Finnlandstrecke, auf der ein deutliches Minimum im August ausgeprägt ist.

Mit der Einstellung der Fahrten des Seedienstes mussten auch die vorliegenden Untersuchungen im Jahre 1935 abgebrochen werden. Zur Abrundung des Bildes war es aber unbedingt notwendig, auch Winter- und Frühjahrswerte zu erhalten. Während dies auf der Finnlandstrecke nicht möglich war, konnte auf der Strecke vor der deutschen Küste, wenn auch nur zwischen Pillau und Swinemünde, die Untersuchung im März 1936 wieder aufgenommen werden.

In der Danziger Bucht wurden während der siebenten Untersuchung vom 26.—28. III. 36 die gleichen Werte angetroffen wie im Oktober. Vor der pommerschen Küste liegen im März die Werte durchweg bei 110 mg. und darüber, während auf den vorhergehenden Untersuchungsfahrten der Wert von 110 mg. erst westlich von Swinemünde überschritten wurde.

Die letzte, achte, Untersuchung vom 27.—30. IV. 36 zeigte besonders interessante Verhältnisse. Das Oderwasser machte sich ausserordentlich stark bis in die Höhe von Kolberg bemerkbar. Vor der Küste Hinterpommerns liegen noch die Werte über 110 mg./l. wie im vorhergehenden Monat. In der pommerschen Bucht liegen schon die Sommerwerte zwischen 100 und 110 mg./l. wie in der Danziger Bucht. Die Gleichförmigkeit vor der deutschen Küste ist damit unterbrochen.

Es wurden in dem vorhergehenden nur die absoluten Ca-Werte besprochen. Ehe auf den relativen Anteil des Ca-Gehaltes gegenüber dem Chloridgehalt eingegangen wird, sei als Ergänzung zu obigen Ergebnissen eine kurze Übersicht über die bis jetzt aus der Ostsee vorliegenden Kalkanalysen gegeben, wie auf die angetroffenen Chlorid-Verhältnisse selbst eingegangen.

Angaben älterer Autoren über den Kalkgehalt der Ostsee.

Über den Kalkgehalt der Ostsee finden sich nur sehr zerstreute Angaben in der älteren und neueren Literatur. Es sind nur eine geringe Anzahl von Analysen durchgeführt worden, und die meisten älteren Autoren begnügen sich damit, die Ergebnisse einiger weniger zu zitieren. "It is true that the calcium content of Baltic waters is but incompletely known. There are in all about forty analyses of old date ...." (Gripenberg, 1934). Wenn auch dahingestellt bleiben muss, wieweit ein Vergleich der älteren Ergebnisse mit den vorliegenden möglich ist, so sei doch der Versuch gemacht, zumal sich die Methode der Kalkbestimmung kaum verändert hat.

Die älteste mir zugängliche Angabe über den Kalkgehalt der Ostsee findet sich bei Goebel (1845), der Analysen an Wässern verschiedener Seebäder am Rigaer Meerbusen vornimmt und die Ergebnisse mit den Angaben noch älterer Autoren (Pfaff, Marcet, Link, Lichtenberg und Seetzen) aus anderen Teilen der Ostsee vergleicht. Die für 16 Unzen[1]) angegebenen Zahlen der Analysenergebnisse sind aber unsicher, da ein Vergleich zu Analysen vor Kiel, Travemünde und Zoppot ergab, dass im Seewasser der esthnischen Küste ein reicherer oder ebenso reicher Kalkgehalt vorhanden wäre. Es kann sich daher nur um Analysen recht ufernahen von der Küste beeinflussten Wassers gehandelt haben. Die Ergebnisse werden daher hier übergangen.

Die ersten vergleichbaren Analysen veröffentlichte 1854 Schrenk von Wasserproben, die Schmidt im Juli 1853 (nach Schmidt, 1878) bei Chudleigh westlich von Narwa im Finnischen Meerbusen entnommen hatte. Liegt auch die Bucht von Narwa ausserhalb der von uns untersuchten Strecke, so seien doch die gefundenen Ca-Werte ergänzend angeführt:

90 m. von der Küste 71·8 mg./l. Ca.
240 m. von der Küste 57·4[2]) mg./l. Ca.

Bemerkenswert ist der höhere Wert unmittelbar an der baltischen Küste. Beide Angaben würden sich den vorliegenden Untersuchungen folgerichtig anschliessen.

Vier Jahre später veröffentlicht Forchhammer (1858) seine Untersuchungen über die Wasserströmungen in dem Sunde bei Helsingør, wobei auch Angaben über den Ca-Gehalt gemacht werden (s. o.). Da dieses Gebiet aber ausserhalb des Zentralbeckens liegt, sei nur darauf hingewiesen, wie auch die übrige sich auf das Kattegat, die Belte und die Sunde beziehende ältere Literatur hier ausseracht gelassen wird.

Derselbe Author veröffentlicht 1859 eine grosse Anzahl von Meerwasseranalysen mit einer Weltkarte, die den Salzgehalt in den verschiedensten Meeren auf Grund seiner Ergebnisse darstellt. Von der Ostsee liegen Untersuchungen an Wasserproben vor, die gelegentlich einer Reise der Fregatte "Bellona" von Kopenhagen nach St. Petersburg und zurück im Jahre 1847 geschöpft wurden. Es ist wahrscheinlich die erste hydrographische Ostseeuntersuchung, die von einem Passagierschiff aus vorgenommen wurde, wenn man von den gelegentlich einer Reise von Swinemünde nach Königsberg Pr. im Jahre 1834 von Alexander v. Humboldt angestellten Temperaturmessungen und Auswertungen absieht (nach Brückmann, 1919). (Die Analysen wurden von F. 1865 noch einmal an anderer Stelle veröffentlicht.) Die in den Tabellen Forchhammer's wiedergegebenen

[1]) Nach Goebel: 1 Pfund = 16 Unzen Medizinalgewicht, während nach dem Pharmazeutischen Kalender (1936) 1 Medizinal-Pfund = 12 Unzen entsprechend 350·784 g. ist!

[2]) Nach Schmidt 1878, 57·1!

Positionen stimmen nicht immer mit den Eintragungen auf seiner Weltkarte überein. Für den Kalkgehalt der Ostsee ergeben sich für das Oberflächenwasser im Jahre 1847 in der Anordnung von Westen nach Osten die nachfolgenden Werte[1]):

29. VII.	Zwischen Hammershus (Bornholm) und Sandhammar (Schonen)	90·0	mg./l.
1. VII.	Zwischen Öland und Gotland	97·9	„
21. V.	58°27′ N.	97·2	„
3. VII.	Eingang zum Finn. Meerbusen, zwei Meilen von Dagö	103·6	„
4. VII.	Finn. Meerbusen zwischen Hogland und Kl.-Tütters	65·7	(69·6)
4. VII.	Zwischen Nervö und Seskjeld	54·3	(64·9)
24. V.	$^1/_2$ Meile vor Kronstadt	12·6	(18·3)
	Kronstadt Kauffarteihafen	16·7	(23·2)

Die Ergebnisse stammen offensichtlich von zwei Fahrten, eine im Mai und eine im Juli. Der niedrige Wert bei Bornholm mag zunächst befremdend wirken, doch muss erinnert werden, dass die Kurven gleichen Salzgehaltes die Ostsee von SW. nach NO. durchlaufen, so dass die Werte an der deutschen Küste stets höher sind als die vor der schwedischen gleicher Breite. Da die wesentliche Quelle des Kalkgehaltes gleich der des Salzgehaltes ist, dürfte der Verlauf der Linien gleichen Kalkgehaltes ähnlich sein.

Die Wasserproben der "Bellona" sind mit Ausnahme der Bornholm-Probe im nördlichen Teil des Zentralbeckens und im Finnischen Meerbusen entnommen. Verglichen mit unseren Werten des Monats Juli stimmen die der "Bellona" gut überein, wenn auch der Wert vor Dagö etwas hoch erscheint.

Im Jahre 1862 erscheint Karl Ernst von Baer's grosse Ostseearbeit, in der zum ersten Male eine spezielle Karte der Ostsee mit den Salzgehaltswerten gegeben wird. Von Baer's Angaben über den Kalkgehalt der Ostsee fussen auf Analysen von Struve und Ad. Goebel für Wasserproben aus verschiedenen meist küstennahen Gebieten.

August 1852.	Bar-Sund zwischen Helsinki und Åbo	101·0	mg./l.
	Degerby, Südküste der Ålands-Inseln	67·9	„
	Furu-Sund, Stockholmer Skären mit Wasser des Mälar-Sees	61·5	„
September 1852.	Offene See, Höhe von Nyköping	135·7	„
	Westerwik, Schwed. Küste Höhe Bornholm	89·5	„
	Karskrona	183·7	„
	Westl. von Malmö	204·3	„
	Landskrona, Öresund	502·8	„
28. VIII. 1854.	Rigaer Meerbusen, zwischen Kaugern und Karlsbad, 150 Schritt vom Ufer	112·2	„
20. VI. 1855.	Soela-Sund, zwischen Ösel und Dagö	96·6	„
23. VII. 1855.	Offene See westlich von Filsand vor Ösel	118·4	„
24. VII. 1860.	Bucht von Hapsal	94·4	„

[1]) F. gibt seine Werte als "Kalk" an. In der Annahme, dass es sich um CaO handelt, wurden die Werte auf Ca umgerechnet. Die Werte sind aber niedriger als die von Schmidt (1878) umgerechneten Werte für Ca. Die Werte von Sch. wurden in Klammern dahinter gesetzt.

Die von K. E. von Baer zusammengestellten Zahlen geben ein deutliches Bild des Ca-Gefälles trotz der Küstennähe, unter der die meisten Proben entnommen wurden. Der hohe Wert vor Nyköping erscheint allerdings unwahrscheinlich.

Anschliessend an die Veröffentlichungen K. E. von Baer's gibt Struve 1864 ergänzende Analysen aus dem Bottnischen Meerbusen. Es wäre sehr zu begrüssen, wenn auch diese einer Nachprüfung unterzogen würden.

Einen vereinzelten Wert aus der Ålands-See nördlich von Grisslehamm gibt Forchhammer (1865):

Oberfläche	94·3 mg./l. Ca
180 m. Tiefe	97·9 mg./l. Ca

Ebenfalls aus dem nördlichen Teil des Zentralbeckens zwischen Ösel und Moon stammt die Wasserprobe, in der A. v. Sass (1866) 101 mg./l. Ca feststellte. Dieser Wert wie der des vorhergenannten Autors fügt sich zwanglos in die durch unsere Untersuchungen gewonnenen Vorstellungen über die Grössenordnung der vorhandenen Ca-Konzentrationen der Ostsee.

Die "Pommerania"-Expeditionen (1871—1873) bringen zwar weitere Erkenntnisse auch über die hydrographischen Verhältnisse der Ostsee, aber keine Angaben über den Kalkgehalt, der uns hier allein interessiert.

1878 veröffentlicht C. Schmidt ausser den bereits bekannten Analysen von Schmidt nach Schrenk (1854), Forchhammer (1859), Struve (1864) und v. Sass (1866) weitere Bestimmungen von M. Glasenapp aus dem Sommer des Jahres 1876:

Arensburg (auf Ösel) tiefeinschneidende Bucht	52·8 mg./l.
Arensburg Reede	106·3 „
Rigaer Meerbusen	103·6 „
Windauer Reede	111·8 „
Libau Reede	112·8 „
"zwischen Öland und dem Kurischen Haff" (!)	119·6 „

Dazu kommt eine von Baron Maydell am 28. IX. 1870 zwischen den Südspitzen von Öland und Gotland geschöpfte Wasserprobe mit 120·6 mg./l. Ca.

Die zusammengestellten Ergebnisse passen sich, soweit sie in das von uns untersuchte Gebiet fallen, den 1935 erhaltenen Sommerwerten an.

1884 veröffentlicht M. Braun eine von C. Schmidt analysierte Wasserprobe aus der Tiefe der Revaler Reede (76·7 m.) westlich der Insel Margen geschöpft am 23. Juli 1883. Es fanden sich 110·3 mg/l. Ca.

Damit sind die Angaben der älteren Autoren abgeschlossen. Von den angegebenen Zahlen beziehen sich nur 20 auf das Zentralbecken! Und diese sind meist auch nur vor der Küste, vom Boot oder sogar vom flachen Strand aus geschöpft worden.

Neuere Angaben über den Kalkgehalt der Ostsee.

In neuerer Zeit hat sich die Ostseehydrographie anderen Aufgaben zugewandt. Es liegt eine reichliche Literatur über die "Alkalinität d.h. den Kalkgehalt oder genauer die an Kohlensäure gebundene Basenmenge" (Schott 1925) vor. Es wird weniger nach den absoluten Kalkmengen als nach den Kohlensäureverhältnissen gefragt (vergl. Schulz, 1921). 1934 weist Gripenberg auf den Mangel an absoluten Ca-Werten hin, da für die gesamte Ostsee nur 40 ältere Angaben vorliegen.

1935 legen Zarins und Ozolins Untersuchungen im Finnischen Meerbusen und vor der lettischen Küste vor. Für das Oberflächenwasser in unserem Untersuchungsbereich werden folgende Werte angegeben:

Position	Datum	φ N	λ E	Ca mg./kg.	$\frac{Ca^{\cdot\cdot}}{Cl'}$ [1]
4. Irbesche Meerenge	22. X. 33	57°43′7″	22°06′6″	0·0916	0·0276
5. Gotland	18. X. 33	57°20′5″	19°56′5″	0·0941	0·0264
6. Pape	17. X. 33	56°15′6″	20°37′2″	0·0971	0·0266
4. Irbesche Meerenge	9. VI. 34	57°41′6″	22°56′8″	0·0903	0·0300
5. Gotland	8. VI. 34	52°20′	19°57′	0·0988	0·0265
6a. Akmenrags	8. VI. 34	56°50′	20°48′	0·0966	0·0265
6. Pape	7. VI. 34	56°11′2″	20°36′	0·0957	0·0265
4. Irbesche Meerenge	17. X. 34	57°41′2″	21°49′7″	0·0995	0·0270
4a. Ventspils	17. X. 34	57°33′	21°02′	0·0981	0·0265
5. Gotland	18. X. 34	57°20′	19°57′	0·0962	0·0265
6a. Akmenrags	2. XI. 34	56°58′	20°45′5″	0·0983	0·0265
6. Pape	2. XI. 34	56°06′8″	20°32′	0·0989	0·0265

[1]) Über den Koeffizienten $Ca^{\cdot\cdot}/Cl'$ vergl. den entsprechenden Abschnitt dieser Arbeit.

Die Werte wurden gravimetrisch gewonnen und geben den Kalkgehalt in Ca gm. für 1 kg. Ostseewasser wieder, sind also direkt mit unseren Angaben nicht vergleichbar.

Ergebnisse der Bestimmungen des Chloridgehaltes.

Ganz im Gegensatz zu den Kalkverhältnissen der Ostsee hat der Chlorid-Haushalt wiederholt eingehende Darstellung gefunden. Über die jahreszeitlichen Verschiebungen des aus dem Cl-Gehalt errechneten Salzgehaltes (S $^0/_{00}$) gibt der Atlas der Deutschen Seewarte (1927) eine Übersicht. Spezialuntersuchungen über den Salzgehalt werden noch dauernd auf allen Fahrten des R. F. D. "Poseidon" behandelt.

Es ist daher überflüssig, den Versuch einer Zusammenstellung der vorhandenen Literatur wie beim Ca-Gehalt anzustellen. Die Ergebnisse der auf unseren Fahrten gefundenen Werte seien nur kurz wiedergegeben, soweit sie im Zusammenhang mit dem Ca-Haushalt von Interesse sind. Der Chloridgehalt wurde nach der Methode von Mohr bestimmt. Die Berechnung von Cl gm./kg. und S $^0/_{00}$ erfolgte nach

der Tabelle von Knudsen. Die Umrechnung von Cl ‰ in Cl gm./Liter geschah mit Hilfe der Tabelle von Kalle (1935).

Auf der zweiten Finnlandreise entnommene Wasserproben (3. bis 8. Juli 1935) zeigen ein Absinken des Salzgehaltes (S ‰)[1]) nach dem Passieren von Windau unter 7 ‰ bis auf 6 ‰ am Eingang des Finnischen Meerbusens. Die Werte der Hin- und Rückfahrt stimmen gut überein, irgendwelche auffallenden Differenzen wie beim Kalkgehalt vor der Baltischen Küste liessen sich nicht feststellen.

Auf der dritten Fahrt Ende Juni ist auf der Finnlandstrecke nur insofern eine Änderung eingetreten, als zwar die Grenze für 7 ‰ kaum verändert ist, aber die Grenze von 6 ‰ eine südlichere Lage erreicht hat.

An den Stellen in der Höhe von Memel, die einen besonders hohen Kalkgehalt aufweisen, finden sich keine auffallenden Werte für S ‰. Wohl aber liegen bei der zweiten Untersuchungsfahrt bei den beiden nördlich anschliessenden Stationen geringere S ‰-Werte als die übrigen vor. Dasselbe trifft für die dritte und vierte Fahrt für die vorhergehende südliche Station zu, während bei der fünften Untersuchung keine Abweichung in diesem Gebiete festzustellen ist. Bei dieser Herabsetzung des Salzgehaltes handelt es sich wohl um den Einfluss von Memelwasser, das entlang der kurischen Küste nach Norden verfrachtet wird, und das sich bis zum 57° N. Br. nach den Beobachtungen der "Pommerania" und der "Tschaika" bemerkbar macht (Ackermann, 1883, S. 156.)

Der Gesamtsalzgehalt vor der pommerschen Küste schwankt auf der dritten Reise zwischen 7·2 und 7·8 ‰ und erweist sich dadurch meist höher als auf der zweiten Reise. Die starken Gegensätze auf der Hin- und Rückreise im Kalkgehalt vor Swinemünde zeigen sich auch im Chloridgehalt. Die Flussmündungen sind dem besonders starken Wechsel von Süss- und Seewasser unterworfen (vergl. Mertens, 1934, S. 425 Kurventafel 17).

In grossen Zügen entsprechen die Juliverhältnisse denen des August im Atlas der Seewarte.

Die Chloridbestimmungen auf der vierten Fahrt im August auf der Finnlandstrecke stellen ein etwas späteres Stadium dar als auf der entsprechenden Salzgehaltskarte. Die 7 ‰-Werte haben sich nordwärts bis zum Ausgang des Rigaer Meerbusens vorgeschoben, während die Grenze der Werte von 6 ‰ fast unverändert blieb. Es besteht so ein Gegensatz zu den Folgerungen aus den Ca-Verhältnissen, gerade auf dieser August-Reise erwies sich das Wasser mit einem Ca-Gehalt unter 100 mg./l. am weitesten nach Süden vorgeschoben. Die Veränderungen des Ca- und Cl-Haushaltes in der Ostsee sind also nicht unbedingt übereinstimmend. Wohl bringt der eingehende Tiefenstrom Ca und Cl im bestimmten Verhältnis mit, diesen gegenüber steht das Flusswasser, was ausserordentlich Cl-arm aber Ca-reich ist, dazu kommt der starke Wechsel in der Zusammensetzung des Flusswassers

[1]) Es werden statt der grossen Zahlen von Cl mg./l. die üblichen aus der Tabelle von Knudsen errechneten Zahlen des Gesamtsalzgehaltes S ‰ angegeben.

im Zusammenhang mit den für die einzelnen Gebiete der Ostsee verschiedenen Witterungsverhältnissen.

Während der Septemberuntersuchung wird die Grenze von 7 ‰ wieder an der Mündung des Rigaer Meerbusens passiert. Den Wert von 6 ‰ erreicht aber Dagö und damit den südlichsten Punkt auf allen Untersuchungen. Die Verhältnisse der Verschiebung des Ca-Gehaltes der vorhergehenden Untersuchung waren also jetzt erst für den Salzgehalt eingetreten. Die Kalkbestimmungen hatten auf der Finnlandstrecke bereits wieder ein Vordringen angezeigt.

Vor der deutschen Küste wird der Wert von 8 ‰ erst westlich von Rügen passiert.

Bei der letzten Fahrt des Jahres 1935 im Oktober liegen Werte über 8 ‰ schon an der Ostküste Rügens. Die Werte vor der pommerschen Küste bleiben unverändert.

Im Jahre 1936 zeigt die siebente Fahrt wie bei den Kalkbestimmungen eine Erhöhung des Salzgehaltes vor der pommerschen Küste. Es sind das die höchsten Werte, die während der Untersuchungsfahrten in diesem Gebiete angetroffen wurden, übereinstimmend mit den Kalkbestimmungen. Die Werte innerhalb der Danziger Bucht sind auffallend niedrig. Das Minimum des Salzgehaltes für die Danziger Bucht liegt nach den Ergebnissen der Beobachtungen im Auftrage der Ministerialkommission zur Untersuchung der Deutschen Meere in Kiel, die vor Hela von 1873—1886 ausgeführt wurden, im April (S e l i g o, 1931). Es könnte dieses Minimum 1936 bereits schon Ende März erreicht sein, zumal nach den in Thorn von 1905—1924 gemessenen Durchschnittswasserständen der Weichsel das Maximum im März liegt (B o r o w i k, 1930).

Die April-Werte entsprechen ganz den Ergebnissen des Kalkgehaltes vor der deutschen Küste. Der Einfluss des Oderwassers bis in die Höhe von Kolberg ist auch aus den Salzgehaltszahlen ersichtlich. Wie beim Kalkgehalt liegen auch hier höhere Werte vor der Küste Hinterpommerns, die noch an die März-Werte erinnern. Abweichend sind die niedrigen Werte vor Hela.

Die Verhältniszahl $Ca^{\cdot\cdot}/Cl'$ in der mittleren Ostsee.

Das Verhältnis von Kalzium zu Chlor ist für den Ozean in der Gleichung

$$c_{Ca} \text{ gm./kg.} = 0{\cdot}02156 \text{ Cl } ‰$$

gegeben. Der Einfluss des Süsswassers setzt in erster Linie den Cl-Gehalt herab, erst in zweiter Linie den Ca-Gehalt, an dem die Flüsse noch relativ reich sind. Das Verhältnis von $Ca^{\cdot\cdot}$ zu Cl' wird daher in der Ostsee ein ganz anderes sein als im Ozean und ist je nach den Mischungsverhältnissen, besonders in der Küstennähe, den verschiedensten Veränderungen unterworfen. Es wird daher unmöglich sein, für die gesamte Ostsee eine ähnliche ausreichende Gleichung aufzustellen wie für den Ozean, sondern höchstens nur für Teilgebiete.

Auf Grund der älteren Literatur gibt Gripenberg, 1934, den $Ca^{\cdot\cdot}/Cl'$-Koeffizienten mit

$$c_{Ca} \text{ gm./kg.} = 0{\cdot}03 \text{ Cl } ‰$$

an. Von Zarins und Ozolins (1935) wird der Wert durch ihre Untersuchungen vor der lettischen Küste auf

$$Ca^{\cdot\cdot}/Cl' = 0{\cdot}0265$$

für 0—70 m. Tiefe verbessert und für die gesamte Ostsee angenommen. Im allgemeinen wird der Wert umso höher sein, je stärker durch den Einfluss des Süsswassers der Cl-Gehalt herabgesetzt wird. Daher fanden die genannten Autoren für die Irbesche Meerenge den Wert von 0·0278 und für den Rigaer Meerbusen 0·02942 im Frühling und Frühsommer und 0·02896 im Sommer und Herbst.

Die sich aus unseren Untersuchungen ergebenden Verhältniszahlen sind aus den Tabellen ersichtlich. Zu deren Bestimmung mussten die nach der Tabelle von Knudsen errechneten Cl-Werte in gm./kg. auf mg./l. umgerechnet werden, um diese Werte in sinngemässe Beziehung zu den Angaben von Ca mg./l. zu setzen[1]). Die Umrechnung erfolgte mit Hilfe der von Kalle (1935) veröffentlichten Tabelle.

Im Durchschnitt ergaben sich daraus für die Strecke Pillau—Helsinki unter Weglassung der in den Häfen oder an den Einfahrten gewonnenen Sonderwerte[2]) folgende Ergebnisse im Jahre 1935:

Juli:		August:		September:	
3.—5.	0·0297	7.—9.	0·0257	4.—6.	0.0275
6.—8.	0·0265	10.—12.	0·0263	7.—9.	0·0270
24.—26.	0·0266				
27.—29.	0·0273				

Die Werte zeigen im einzelnen den starken Wechsel des hydrographischen Zustandes innerhalb kurzer Zeit.

Im Durchschnitt ergibt sich für die Strecke:

$$\text{Pillau—Memel: } Ca^{\cdot\cdot}/Cl' = 0{\cdot}0269.$$

Der Wert ist also höher als der von den genannten lettischen Autoren in diesem Gebiete errechnete. Dagegen stimmt mit ihren Angaben der einmalige Wert der Strecke:

$$\text{Pillau—Memel: } Ca^{\cdot\cdot}/Cl' = 0{\cdot}0265$$

überein. Die Werte für die Strecke Pillau—Swinemünde ergaben folgendes Bild (1935/36):

Juli:		September:	Oktober:	März:	April:
20./21.	0·0256	4./5. 0·0257	23./24. 0·0260	26./27. 0·0284	27./28. 0·0274
23./24.	0·0264			27./28. 0·0268	29./30. 0·0260

[1]) Praktisch muss dieses Verhältnis $\frac{\text{mg./l. Ca}}{\text{mg./l. Cl}}$ auf dasselbe herauskommen, wie die von den genannten Autoren verwandte Beziehung $\frac{\text{gm./kg. Ca}}{\text{Cl } ‰}$

[2]) In den Tabellen mit × bezeichnet.

Der daraus errechnete Durchschnittswert ist:

Pillau—Swinemünde: $Ca^{\cdot\cdot}/Cl' = 0{\cdot}0265$

also übereinstimmend mit dem Wert der Memeler Strecke und dem von Zarins und Ozolins für die ganze Ostsee angegebenen.

Für das Gebiet westlich von Swinemünde bis Travemünde liegen nur wenige Angaben vor.

Juli:		September:		Oktober:	
21.	0·0245	5.	0·0242	23.	0·0253
23.	0·0256				

daraus ergibt sich die Durchschnittszahl von

Swinemünde—Travemünde: $Ca^{\cdot\cdot}/Cl' = 0{\cdot}0249$.

Die Verhältniszahlen steigern sich also von Westen nach Osten, d.h., die *absoluten* Werte des Ca-Gehaltes nehmen zwar, wie schon die älteren Untersuchungen zeigen konnten, von Westen nach Osten und Norden ab, die Abnahme des Ca-Gehaltes ist aber geringer als die der Chloride, so dass der Ca/Cl-Koeffizient in derselben Richtung grösser wird, der *relative* Ca-Gehalt nimmt also zu.

Es besteht also folgende Reihe:

Ozean	0·0216
Swinemünde/Travem.	0·0249
Swinemünde/Pillau	0·0265
Pillau/Memel	0·0265
Pillau/Helsinki	0·0269
Irbesche Meerenge	0·0278
Rigaer Meerbusen	0·0290—94

letztere beiden Zahlen nach den lettischen Autoren.

Der von Zarins und Ozolins angegebene Koeffizient wird für wesentliche Teile der Ostsee bestätigt, wenn auch keinesfalls für die gesamte Ostsee, und er ausserdem nach unseren Berechnungen für den von den beiden Autoren untersuchten Ostsee-Abschnitt etwas zu klein ist.

Die genannten Werte, besonders der für die mittlere Ostsee zwischen Pillau und Swinemünde mit 0·0265 festgestellte Wert, gestattet es also aus der Cl-Bestimmung den Ca-Gehalt als gm./kg. oder nach erfolgter Umrechnung in Cl mg./l. entsprechend anzugeben.

Eine weitere Verbesserung und Präzisierung des Koeffizienten müsste durch weitere Untersuchungen erfolgen, die eine gleichmässigere Berücksichtigung der verschiedenen Jahreszeiten als es bei unseren Untersuchungen möglich war, enthalten. Darin scheint auch der wesentliche Grund der Differenz unserer Werte mit den lettischen zu liegen, da auf dieser Strecke im östlichen Teile der Ostsee nicht wie vor der deutschen Küste genügend lange Untersuchungen durchgeführt wurden.

Es darf also für die gesamte *mittlere* Ostsee der Wert

$Ca^{\cdot\cdot}/Cl' = 0{\cdot}0265$ angenommen werden.

Zusammenfassung.

Als Beitrag zur Hydrographie der mittleren Ostsee, zugleich zur Klärung der Verhältnisse der Wanderwege des Lachses *(Salmo salar)*, wurden vom Juni 1935 bis April 1936 vom Fischerei-Institut der Universität Königsberg Pr. von fahrplanmässigen Passagierschiffen aus Untersuchungen in der mittleren Ostsee vor der deutschen und baltischen Küste angestellt. Im vorliegenden werden die Ergebnisse über den Kalkgehalt der mittleren Ostsee und seine Beziehungen zum Chloridgehalt wiedergegeben.

Der Kalkgehalt wurde direkt nach Fällung als Kalziumoxalat titrimetrisch bestimmt.

Die Ca-Konzentrationen von den einzelnen Positionen sind jahreszeitlichen Schwankungen unterworfen, ähnlich den Cl-Konzentrationen, doch nicht gleichlaufend.

Der Kalkgehalt des Zentralbeckens erweist sich von Ösel bis Rügen relativ einheitlich, während östlich bezw. westlich dieses Gebietes sprungartige Veränderungen auftreten.

Die Untersuchung der Ergebnisse der älteren spärlichen Literatur über den Kalkgehalt der Ostsee bringt, von einigen Ausnahmen abgesehen, Übereinstimmung mit dem vorgefundenen Ca-Gefälle, das von Westen nach Osten abnimmt.

Für das Verhältnis von $Ca^{\cdot\cdot}$ zu Cl' wurde der von Zarins und Ozolins (1935) vorgeschlagene Wert von

$$Ca^{\cdot\cdot}/Cl' = 0{\cdot}0265$$

für das Zentralbecken bestätigt. Ausserdem zeigten die Verhältniszahlen, dass der absolute Kalkgehalt zwar von Westen nach Osten und Norden abnimmt, der relative aber unter dem Einfluss der Süsswasserzuflüsse in der gleichen Richtung wächst.

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Tabelle I. **Strecke: Pillau—Helsinki 3.—5. VII. 1935.**

Dat.	φ N.	λ E.	Cl ‰	S ‰	Cl mg./l.	Ca mg./l.	Ca''/Cl'
3. VII.	Molenkopf Pillau		3·458	6·28	3468	108	0·0311 ×
	Höhe Brüsterort, 5·5 SM.		3·707	6·73	3717	114	0·0307 ×
	55°17′	20°0′	3·955	7·25	3975	114	0·0287
	55°35′	20°8′	3·920	7·09	3940	114 Δ	0·0289
	55°52′	20°18′	3·813	6·91	3833	102	0·0266
4. VII.	56°10′	20°27′	3·849	6·98	3869	112	0·0290
	56°28′	20°35′	3·884	7·03	3904	112	0·0287
	56°37′	20°40′	3·849	6·98	3869	—	—
	56°44′	20°45′	3·849	6·98	3869	108	0·0279
	57°14′	20°55′	3·813	6·91	3833	112	0·0292
	57°24′	21°4′	3·707	6·73	3717	112	0·0301
	57°45′	21°12′	3·742	6·78	3752	102	0·0272
	58°7′	21°19′	3·724	6.74	3734	104	0·0279
	58°24′	21°30′	3·566	6·47	3576	104	0·0291
	58°43′	21°43′	3·566	6·47	3576	100	0·0280
	59°2′	22°3′	3·529	6·40	3539	98	0·0269
	59°11′	22°27′	3·423	6·20	3433	92	0·0268
	59°21′	23°1′	3·352	6·08	3362	90	0·0268
5. VII.	59°29′	23°29′	3·352	6·08	3362	90	0·0268
	59°40′	24°2′	3·103	5·63	3113	86	0·0276
	59°48′	24°28′	3·068	5·57	3078	80	0.0260
	Skären von Helsinki		3·022	5·48	3032	86	0·0284 ×
	Höhe von Sveaborg		2·845	5·17	2855	76	0·0376 ×
	Helsinki Osthafen		2·845	5·17	2855	76	0·0376 ×

Tabelle II. **Strecke: Helsinki—Pillau 6.—8. VII. 1936.**

6. VII.	Helsinki Osthafen		2·632	4·78	2642	58	0·0220 ×
	Skären		2·667	4·85	2677	68	0·0254 ×
	59°56′	24°56′	2·951	5·35	2961	78	0·0263
	59°54′	24°29′	3·174	5·75	3184	86	0·0270
7. VII.	59°38′	23°56′	3·210	5·82	3220	82	0·0255
	59°27′	23°27′	3·174	5·75	3184	86	0·0270
	59°18′	22°53′	3·458	6·28	3468	90	0·0260
	58°50′	21°45′	3·565	6·47	3575	—	—
	58°33′	21°31′	3·600	6·53	3610	94	0·0260
	58°12′	21°18′	3·742	6·78	3752	98	0·0261
	57°51′	21°11′	3·742	6·78	3752	98	0.0261
	57°32′	21°5′	3·778	6·83	3798	—	—
	57°10′	21°0′	3·831	6·93	3851	104	0·0270
8. VII.	56°21′	20°36′	3·920	7·11	3940	106	0·0269
	56°3′	20°27′	3·884	7·03	3904	104	0·0266
	55°39′	20°13′	3·813	6·91	3833	108 Δ	0·0282
	55°26′	20°5′	3·884	7·03	3904	102	0·0261
	Höhe Brüsterort		3·849	6·98	3869	104	0·0269 ×
	Molenkopf Pillau		3·281	5·95	3291	92	0·0280 ×

Tabelle III. Strecke: Pillau—Travemünde 20.—21. VII. 1935.

Dat.	φ N.	λ E.	t °	Cl ‰	S ‰	Cl mg./l.	Ca mg./l.	Ca″/Cl′
20. VII.	Molenkopf Pillau		19·2	3·547	6·44	3557	100	0·0281 ×
	54°32′	19°9′	19·0	3·920	7·11	3940	104	0·0264
	2 SM. NW. von Zoppot		17·6	4·044	7·32	4064	106	0·0261
	54°48′	18°26′	17·8	4·115	7·47	4135	104	0·0252
	54°51′	17°40′	17·9	4·178	7·57	4198	106	0·0253
	54°43′	16°50′	17·9	4·143	7·50	4163	108	0·0259
21. VII.	54°28′	15°58′	17·9	4·204	7·61	4224	100	0·0237
	54°12′	15°11′	18·2	4·196	7·61	4216	108	0·0256
	54°0′	14°29′	18·4	4·062	7·36	4082	108	0·0265
	Swinemünde Molenkopf		18·8	3·529	6·40	3539	98	0·0277 ×
	54°25′	13°52′	17·8	4·356	7·90	4376	110	0·0251
	54°42′	13°11′	17·1	4·817	8·73	4847	120	0·0246
	54°30′	12°28′	17·1	5·421	9·81	5451	130	0·0238
	Warnemünde Reede		—	6·105	11·06	6145	150	0·0244
	54°9′	11°30′	—	—	—	—	156	—

Tabelle IV. Strecke: Travemünde—Pillau 23.—24. VII. 1935.

Dat.	φ N.	λ E.	t °	Cl ‰	S ‰	Cl mg./l.	Ca mg./l.	Ca″/Cl′
23. VII.	Nördl. Kalkhorst 2 SM.		18·7	6·496	11·76	6546	156	0·0238
	54°18′	11°47′	18·0	7.383	13·35	7453	186	0·0250
	54°34′	12°35′	19·0	5·953	10·77	5993	146	0·0244
	54°4′30″	13°26′	17·0	4·498	8·15	4528	120	0·0265
	54°17′	13°56′	17·8	4·356	7·90	4376	124	0·0283
	Swinemünde Molenkopf		18·1	3·955	7·25	3975	132	0·0332 ×
	54°6′30″	14°54′	17·6	4·249	7·70	4269	104	0·0244
	54°21′	15°37′	17·8	4·285	7·77	4305	120	0·0279
24. VII.	54°36′	16°25′	18·2	3·951	7·16	3971	106	0·0267
	54°50′	17°13′	17·8	4·062	7·36	4082	110	0·0269
	54°52′	18°0′	17·8	4·026	7·30	4046	106	0·0262
	54°42′	18°48′	18·0	4·097	7·43	4197	108	0·0262
	54°29′	18°49′	17·9	4·178	7·57	4198	106	0·0253
	54°37′	19°41′	16·7	4·044	7·32	4064	112	0·0276

Tabelle V. Strecke: Pillau—Memel—Pillau 24.—25. VII. 1936.

Dat.	φ N.	λ E.	t °	Cl ‰	S ‰	Cl mg./l.	Ca mg./l.	Ca··/Cl′
24. VII.	54°50′30″	19°50′	17·4	3·920	7·11	3940	102	0·0259
	55°4′30″	20°1′	17·1	3·973	7·20	3993	103	0·0258
	55°15′	20°18′	17·6	3·955	7·25	3975	106	0·0267
	55°25′	20°34′	16·6	3·884	7·03	3903	108	0·0277
	55°35′	20°50′	17·8	3·920	7·11	3940	102	0·0259
	Memel 1 SM. NW. Molenkopf		18·1	3·565	6·47	3575	100	0·0280 ×
25. VII.	55°38′	20°54′30″	17·5	3·813	6·91	3833	102	0·0266
	55°25′	20°38′	17·5	4·026	7·30	4046	106	0·0262
	55°14′	20°16′	15·7	3·955	7·17	3975	106	0·0267
	55°3′	19°59′	16·4	3·955	7·17	3975	104	0·0262
	4 SM. querab Palmnicken		16·9	3·991	7·23	4011	111	0·0277

Tabelle VI. Strecke: Pillau—Helsinki 24.—26. VII. 1935.

Dat.	φ N.	λ E.	t °	Cl ‰	S ‰	Cl mg./l.	Ca mg./l.	Ca··/Cl′
24. VII.	Pillau Molenkopf		—	2·997	5·45	3007	92	0·0306 ×
	Höhe Brüsterort		—	3·955	7·25	3975	102	0·0257 ×
	55°18′	20°0′	16·0	4·026	7·30	4046	104	0·0257
	55°36′	20°10′	—	3·813	6·91	3833	104	0.0271
	55°54′	20°18′	17·0	3·884	7·03	3904	104	0·0266
25. VII.	56°16′	20°31′	—	3·849	6·98	3869	100	0·0258
	56°36′	20°44′	16·9	3·884	7·03	3904	104	0·0266
	57°15′	20°57′	16·6	3·884	7·03	3904	104	0·0266
	57°31′	21°3′	—	3·849	6.98	3869	102	0·0264
	57°47′	21°9′	14·7	3·760	6·82	3780	98	0·0259
	58°4′	21°15′	—	3·707	6·73	3717	100	0·0269
	58°21′	21°22′	13·1	3·707	6·73	3717	100	0·0269
	58°45′	21°26′	—	3·671	6·65	3681	100	0·0272
	58°57′	21°26′	13·0	3·423	6·20	3433	98	0·0285
	59°3′	22°3′	—	3·458	6·28	3468	89	0·0257
	59°12′	22°31′	14·5	3·387	6·15	3397	89	0·0262
26. VII.	59°30′	23°22′	15·2	3·192	5·79	3202	86	0·0269
	59°42′	23°55′	—	2·951	5·35	2961	80	0·0270
	59°50′	24°30′	16·4	2·756	5·01	2766	74	0·0268
	Grahara Leuchtturm		—	3·281	5·95	3291	90	0·0273 ×
	Hafen Helsinki Einfahrt		—	2·880	5·23	2890	84	0·0291 ×

Tabelle VII. Strecke: Helsinki—Pillau 27.—29. VII. 1935.

Dat.	φ N.	λ E.	t °	Cl ‰	S ‰	Cl mg./l.	Ca mg./l.	$Ca^{\cdot\cdot}/Cl'$
27. VII.	Hafen Helsinki			2·720	4·94	2730	78	0·0256 ×
	Hafen Ausfahrt			2·880	5·23	2890	80	0·0277 ×
	Skären			2·969	5·39	2979	80	0·0269 ×
	59°50′	24°31′		2·845	5·17	2855	80	0·0280
28. VII.	59°38′	23°56′		3·068	5·57	3078	84	0·0273
	59°29′	23°22′		3·103	5·63	3113	92	0·0296
	59°17′	22°47′		3·423	6·20	3433	94	0·0274
	59°8′	22°16′		3·458	6·28	3468	87	0·0251
	58°54′	21°49′		3·458	6·28	3468	94	0·0271
	58°30′	21°22′		3·701	6·73	3711	100	0·0269
	58°5′	21°15′		3·701	6·73	3711	102	0·0275
	57°46′	21°9′		3·689	6·69	3699	102	0·0276
	57°27′	21°2′		3·831	6·94	3851	100	0·0260
	57°12′	20°56′		3·920	7·11	3940	108	0·0274
	56°53′	20°49′		3·849	6·98	3869	106	0·0274
29. VII.	56°35′	20°38′		3·849	6·98	3869	110	0·0284
	56°19′	20°30′		3·955	7·18	3975	106	0·0267
	55°45′	20°13′		3·955	7·18	3975	122 Δ	0·0307
	55°29′	20°6′		3·973	7·20	3993	114	0·0285
	55°13′	19°59′		3·955	7·18	3975	102	0·0257
	54°58′	19°50′		3·991	7·23	4011	100	0·0249
	Einfahrt Pillau			3·426	6·22	3446	107	0·0311 ×

Tabelle VIII. Strecke: Pillau—Helsinki 7.—9. VIII. 1935.

Dat.	φ N.	λ E.	t °	Cl ‰	S ‰	Cl mg./l.	Ca mg /l.	$Ca^{\cdot\cdot}/Cl'$
7. VIII.	Pillau Molenkopf			2·596	4·72	2606	96	0·0368 ×
	55°2′	19°53′		4·026	7·30	4046	104	0·0257
	55°21′	20°0′		4·026	7·30	4046	102	0·0252
	55°41′	20°8′		4·026	7·30	4046	102	0·0252
	56°2′	20°17′		3·991	7·25	4011	104	0·0259
8. VIII.	56°20′	20°25′		3·920	7·11	3940	102	0·0259
	56°40′	20°33′		3·991	7·25	4011	102	0·0254
	57°2′	20°46′		3·920	7·11	3940	102	0·0259
	57°22′	20°55′		3·920	7·11	3940	100	0·0254
	57°42′	21°6′		3·849	6·98	3869	96	0·0248
	58°5′	21°16′		3·742	6·78	3752	94	0·0251
	58°21′	21°25′		3·671	6·65	3681	96	0·0261
	58°43′	21°36′		3·742	6·78	3752	96	0·0256
	58°57′	21°54′		3·387	6·15	3397	94	0·0277
	59°10′	22°25′		3·529	6·40	3539	—	—
	59°19′	22°55′		3·423	6·28	3433	84	0·0245
9. VIII.	59°28′	23°27′		3·387	6·15	3397	86	0·0253
	59°41′	24°5′		3·022	5·48	3032	80	0·0264
	59°53′	24°41′		3·040	5·52	3050	80	0·0262
	Helsinki Lotsenstation			2·987	5·43	2997	78	0·0260 ×

Tabelle IX. Strecke: Helsinki—Pillau 10.—12. VIII. 1935.

Dat.	φ N.	λ E.	t °	Cl ‰	S ‰	Cl mg./l.	Ca mg./l.	Ca″/Cl′
10. VIII.	Lotsenstation Helsinki			2·951	5·35	2961	80	0·0270 ×
	59°49′	24°29′		2·912	5·30	2922	80	0·0274
11. VIII.	59°37′	23°55′		2·951	5·35	2961	80	0·0270
	59°27′	23°23′		3·245	5·90	3255	85	0·0261
	59°17′	22°47′		3·458	6·28	3468	84	0·0242
	59°8′	22°17′		3·494	6·33	3504	96	0·0274
	58°55′	21°48′		3·565	6·47	3575	—	—
	58°34′	21°33′		3.671	6·65	3681	98	0·0266
	58°17′	21°21′		3·742	6·78	3752	102	0·0272
	57°39′	21°6′		3·884	7·03	3904	100	0·0256
	57°20′	21°0′		3·991	7·23	4011	102	0·0254
	56°58′	20°51′		3·937	7·14	3957	102	0·0258
	56°35′	20°40′		3·955	7·18	3975	102	0·0258
12. VIII.	56°11′	20°27′		3·955	7·18	3975	104	0·0263
	55°51′	20°14′		3·955	7·18	3975	108 Δ	0·0272
	55°31′	20°1′		3·671	6·65	3691	100	0.0271
	55°11′	19°50′		3·991	7·23	4011	106	0·0264
	54°51′	19°50′		3·991	7·23	4011	104	0·0259
	Querab Tenkitten			3·387	6·15	3397	96	0·0283 ×

Tabelle X. Strecke: Pillau—Travemünde 4.—5. IX. 1935.

4. IX.	Pillau Molenkopf		18·1	3·412	6·19	3422	100	0·0292
	54°31′	19°0′	18·2	3·884	7·03	3904	—	—
	Reede Zoppot		18·5	3·884	7·03	3904	100	0·0256
	54°33′	18°48′	18·1	3·849	6·98	3869	100	0·0258
	54°50′	18°28′	17·1	4·026	7·30	4046	100	0·0247
	54°51′	17°44′	17·2	4·143	7·50	4163	106	0·0255
	54°48′	16°58′	17·4	4·062	7·36	4082	104	0·0255
5. IX.	54°43′	16°9′	17·2	4·080	7·39	4100	102	0·0249
	54°37′	15°25′	16.8	4·097	7·43	4117	—	—
	54°32′	14°42′	16·0	4·160	7·54	4180	114	0·0273
	54°26′	13°56′	17·2	4·370	7·92	4390	113	0·0257
	Binz Brücke		17·6	4·320	7·83	4340	114	0·0263
	Vor Stubbenkammer		16·4	4·285	7·77	4305	110	0·0256
	54°42′	13°24′	16·4	4·320	7·83	4340	108	0·0249
	54°40′	13°0′	13·4	4·533	8·21	4553	111	0.0244
	54°36′	12°40′	15·0	4·853	8·78	4883	118	0·0242
	54°26′	12°25′	14·8	4·640	8·41	4670	118	0·0253
	54°17′	12°11′	15·5	5·279	9·56	5309	130	0·0241
	Warnemünde Molenkopf		16·6	4·959	8·98	4989	126	0·0253 ×
	54°12′	11°48′	16·0	6·673	12·07	6723	178	0·0265
	54°7′	11°24′	15·2	5·669	10·26	5709	144	0·0252
	54°1′	11°1′	16·5	6·815	12·34	6875	120	0·0176

Tabelle XI. Strecke: Pillau—Helsinki 4.—6. IX. 1935.

Dat.	φ N.	λ E.	t °	Cl ‰	S ‰	Cl mg./l.	Ca mg./l.	Ca˝/Cl′
4. IX.	Pillau Molenkopf			3·742	6·78	3752	102	0·0272×
	55°0′	19°50′		3·920	7·11	3940	108	0·0274
	55°19′	20°0′		3·920	7·11	3940	106	0·0269
	55°40′	20°11′		4·026	7·30	4046	108	0·0267
	56°0′	20°20′		3·991	7·23	4021	106	0·0264
5. IX.	56°22′	20°31′		3·920	7·11	3940	106	0·0269
	56°41′	20°41′		3·813	6·91	3833	112	0·0292
	57°2′	20°50′		3·813	6·91	3833	112	0·0292
	57°23′	20°59′		3·742	6·78	3752	—	—
	57°43′	21°8′		3·813	6·91	3833	111	0·0290
	58°3′	21°16′		3·707	6·73	3717	106	0·0285
	58°24′	21°25′		3·600	6·53	3610	96	0·0266
	58°43′	21°38′		3·582	6·49	3592	96	0·0267
	59°2′	22°3′		3·565	6·47	3575	90	0·0252
	59°11′	22°29′		3·316	6·02	3326	102	0·0307
	59°21′	23°0′		3·068	5·57	3078	82	0·0266
6. IX.	59°30′	23°32′		2·809	5·10	2819	80	0·0284
	59°45′	24°29′		2·880	5·23	2890	76	0·0263
	59°51′	24°38′		2·632	4·78	2642	—	—
	Sveaborg			2·774	5·03	2784	72	0·0259×
	Einfahrt Hafen Helsinki			2·525	4·60	2535	72	0·0284×

Tabelle XII. Strecke: Helsinki—Pillau 7.—9. IX. 1935.

Dat.	φ N.	λ E.	t °	Cl ‰	S ‰	Cl mg./l.	Ca mg./l.	Ca˝/Cl′
7. IX.	Helsinki Ausfahrt			2·667	4·85	2677	68	0·0254×
	Feuerschiff vor Helsinki			2·596	4·72	2606	72	0·0276
	59°48′	24°21′		2·713	4·92	2723	74	0·0272
8. IX.	59°36′	23°49′		2·819	5·12	2839	84	0·0296
	59°25′	23°14′		2·819	5·12	2839	—	—
	59°16′	22°37′		3·210	5·82	3230	84	0.0260
	59°3′	22°4′		3·529	6·40	3549	90	0·0254
	58°44′	21°34′		3·671	6·65	3691	98	0·0266
	58°25′	21°30′		3·600	6·53	3620	—	—
	58°8′	21°15′		3·671	6·65	3691	98	0·0266
	57°48′	21°5′		3·778	6·85	3798	104	0·0261
	57°28′	20°57′		3·955	7·18	3975	—	—
	57°8′	20°48′		3·884	7·03	3904	114	0·0292
	56°44′	20°31′		3·884	7·03	3904	102	0·0261
	56°24′	20°24′		3·991	7·23	4011	108	0·0269
9. IX.	55°58′	20°12′		3·920	7·11	3940	114Δ	0·0289
	55°37′	20°0′		3·991	7·23	4011	106	0·0264
	55°17′	19°54′		3·991	7·23	4011	102	0·0254
	54°58′	19°47′		3·955	7·18	3975	106	0·0267
	vor Pillau			3·920	7·18	3940	106	0·0269
	Einfahrt Pillau			3·245	5·90	3255	97	0·0298×

Tabelle XIII. Strecke: Kiel—Pillau 23.—24. X. 1935.

Dat.	φ N.	λ E.	t °	Cl ‰	S ‰	Cl mg./l.	Ca mg./l.	Ca··/Cl′
23. X.	54°30′	11°23′	—	11·008	19·90	11138	279	0·0250
	54°32′	12°30′	—	8·474	15·32	8564	212	0·0248
	54°43′	13°19′	10·9	4·640	8·41	4660	120	0·0258
	Höhe Stubbenkammer		11·2	4·462	8·08	4482	112	0·0250
	Höhe Binz		10·9	4·569	8.28	4589	116	0·0253
	54°18′	14°0′	10·35	4·370	7·92	4390	112	0·0255
	54°9′	14°8′	11·1	4·249	7·70	4269	106	0·0248
	54°5′	14°22′	10·4	4·062	7·36	4082	108	0·0265
	Heulboje vor Swinemünde		9·4	3·174	5·75	3184	90	0·0283 ×
	54°8′	14°58′	10·1	4·214	7·63	4234	106	0·0250
	54°23′	15°44′	10·9	3·991	7·23	4011	106	0·0264
24. X.	54°44′	17°0′	10·55	4·143	7·50	4163	104	0·0250
	54°56′	17°35′	11·1	4·097	7·43	4117	104	0·0253
	54°53′	18°14′	10·7	4·143	7·50	4163	104	0·0250
	54°40′	18°48′	11·6	3·600	6·53	3610	104	0·0288
	Zoppot Reede		10·4	3·920	7·11	3940	100	0·0254
	54°33′	19°15′	11·3	4·026	7·30	4046	106	0·0262
	54°35′	19°35′	11·7	3·955	7·18	3975	106	0·0267
	Molenkopf Pillau		10·5	3·884	7·03	3904	106	0·0272 ×

Tabelle XIV. Strecke: Pillau – Swinemünde 26.—27. III. 1936.

Dat.	φ N.	λ E.	t °	Cl ‰	S ‰	Cl mg./l.	Ca mg./l.	Ca··/Cl′
26. III.	Pillau Molenkopf		3·0	1·734	3·16	1734	80	0·0461 ×
	54°33′	19°17′	2·7	4·107	7·45	4127	102	0·0247
	54°29·5′	18°52′	3·3	3·068	5·57	3078	102	0·0331
	Reede Zoppot		3·4	3·671	6·65	3681	106	0·0288
	54°45′	18°38·5′	2·5	4·178	7·57	4198	110	0·0262
	54°52′	17°49′	2·7	4·143	7·50	4163	124	0·0298
	54°47′	17°0′	2·4	4·214	7·63	4234	112	0·0265
	54°33′	16°15′	2·3	4·231	7·67	4251	110	0·0259
27. III.	54°18′	15°19′	2·4	4·267	7·74	4287	126	0·0294
	54°6′	14°49′	2·4	4·204	7·62	4224	134	0·0317
	Reede Swinemünde		1·9	4·143	7·51	4163	118	0·0283
	Liegeplatz Swinemünde		3·9	0·472	—	472	66	0·1398 ×

Tabelle XV. Strecke: Swinemünde—Pillau 27.–28. III. 1936.

Dat.	φ N.	λ E.	t °	Cl ‰	S ‰	Cl mg./l.	Ca mg./l.	Ca˝/Cl′
27. III.	Liegeplatz Swinemünde		4·4	0·401	—	401	62	0·1546 ×
	Swine-Mündung		3·6	1·014	1·86	1014	66	0·0651 ×
	54°05′	14°42′	2·5	4·285	7·77	4305	122	0·0283
	54°18′	15°28′	2·2	4·249	7·70	4269	110	0·0258
	54°32′	16°13′	2·2	4·285	7·77	4305	126	0·0293
28. III.	54°47′	16°59′	2.4	4·214	7·64	4234	108	0·0255
	54°51′	17°48′	2.3	4·249	7·70	4269	110	0·0258
	54°44′	18°42′	2·55	3·653	6·63	3663	100	0·0273
	Ausfahrt Zoppot		3·3	3·742	6·78	3752	101	0·0269
	54°30′	18°56′	2·3	4·072	7·38	4092	108	0·0264
	53°34′	19°17′	2·4	3·965	7·19	3985	104	0·0261
	54°37′	19°42′	2·4	3·930	7·12	3950	106	0·0268
	Pillau Mølenkopf		3·3	2·525	4·59	2535	80	0·0316 ×

Tabelle XVI. Strecke: Pillau—Swinemünde 27.—28. IV. 1936.

Dat.	φ N.	λ E.	t °	Cl ‰	S ‰	Cl mg./l.	Ca mg./l.	Ca˝/Cl′
27. IV.	Ausfahrt Pillau		8·4	3·415	6·19	3425	100	0·0292 ×
	54°30′	18°56·5′	5·0	4·062	7·36	4082	108	0·0265
	Zoppot Reede		6·7	3·920	7·11	3940	112	0·0284
	54°38′	18°52′	5·0	4·097	7·43	4117	110	0·0267
	54°52′	18°3′	5·0	4·143	7·50	4163	110	0·0264
	54°47·5′	17°12·5′	5·6	4·196	7·61	4216	116	0·0275
	54°34′	16°22′	6·3	4·026	7·30	4046	116	0·0287
28. IV.	54°22′	15°43′	4·4	4·115	7·46	4135	114	0·0276
	54°9′	14°56′	6·3	3·742	6·78	3752	104	0·0277 ×
	53°39′	14°25′	7·2	2·744	4·98	2755	92	0·0334 ×

Tabelle XVII. Strecke: Swinemünde—Pillau 29.—30. IV. 1936.

Dat.	φ N.	λ E.	t °	Cl ‰	S ‰	Cl mg./l.	Ca mg./l.	Ca˝/Cl,
29. IV.	Ausfahrt Swinemünde		6·8	3·671	6·65	3681	104	0·0283 ×
	54°10′	15°3′	7·0	3·742	6·78	3752	108	0·0288 ×
	54°23′	15°47′	4·5	4·143	7·50	4163	108	0·0259
30. IV.	54°38′	16°34′	5·8	4·214	7·64	4234	112	0·0265
	54°50′	16°27′	6·2	4·196	7·60	4216	116	0·0275
	54°52′	18°16′	5·8	3·795	6·88	3815	114	0·0299
	54°35′	18°50′	5·7	3·955	7·17	3975	82	0·0206
	Zoppot Reede		7·5	4·231	7·67	4251	108	0·0254
	54°32′	19°0′	5·9	3·955	7·17	3975	106	0·0267
	55°34′	19°20′	6·6	4·143	7·50	4163	106	0·0255
	von Pillau		6·4	3·352	6·08	3362	98	0·0291 ×

On Certain Inter-Relations between Phytoplankton and Zooplankton under Experimental Conditions.

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Introduction.

IN the past it has been repeatedly observed that on the whole, though by no means always, the abundance of animals in the plankton varies, both in time and space, inversely with that of the plants. These observations received little notice or discussion until Hardy (1935) reviewed fully the literature referring to them and added further detailed evidence of such an inverse relationship from the plankton surveys of South Georgia and elsewhere. He puts forward the hypothesis of Animal Exclusion linking the phenomenon with that of the vertical migration of the zooplankton. He has more recently (1936) defined the hypothesis in the following words. "The direct excluding effect is considered to be one in a vertical rather than a horizontal plane, the exclusion effect seen in plan being secondarily produced by water movements. The hypothesis may be briefly stated thus: vertically migrating animals which live for part of the twenty-four hours below the phytoplankton zone come up into that zone for a period inversely proportional to the density of the phytoplankton. The extent of the exclusion from the phytoplankton zone may vary for different species or for different stages in the development of the same species of animal."

Harvey (1934), who found an inverse phyto-zooplankton relationship in the Plymouth area, explained the phenomenon by suggesting that here the phytoplankton crop is being heavily grazed by the herbivores in the zooplankton. Both Harvey and Hardy agree that the two theories are not incompatible, and Hardy gives evidence of the effects of grazing in parts of the South Georgia survey but does not consider that it can explain the greater part of the inverse phyto-zooplankton distribution found there.

Professor H a r d y, who was anxious that laboratory experiments should be carried out to test the hypothesis but was unable through pressure of other work to undertake them himself, gave me the opportunity of making the first experiments to investigate the effects of diatom cultures of various strengths upon plankton animals introduced therein. Preliminary experiments were made in 1934 and the results briefly quoted by H a r d y (1935, p. 342). In addition I wished to investigate the rates of consumption of the phytoplankton by the animals.

Only a very limited amount of time, in short intervals between routine plankton survey work, has been available for the experiments and at present, for this reason, it is unfortunately impossible to carry them further. However, it seems desirable that an account of these preliminary experiments should be put on record, for the results, whilst showing only certain tendencies, suggest that they are worthy of further investigation. From the beginning and most of all when trying to assess the results as a whole, it appeared clear that the most detailed investigation possible is necessary for the analysis of relationships of this type. Such an investigation should consider fully the many different physical and chemical factors involved. When first planning the work I had anticipated the chemical side would have been undertaken by a colleague, a biochemist; but through his departure to take up an appointment elsewhere this part of the work had to be abandoned.

The experiments were of three kinds and will be described under the following headings.

(1) *Exclusion experiments,* to investigate the possible comparative avoidance by animals of illuminated zones of phytoplankton of differing concentration.

(2) *Lethal experiments,* to observe the possible toxic effects of differing concentrations of phytoplankton upon animals by measuring their length of life when confined to cultures of different strengths.

(3) *Feeding experiments,* to investigate the rate of consumption of the phytoplankton by the animals.

For the phytoplankton, practically pure cultures of *Nitzschia closterium* (Ehrenberg) were used (obtained originally from Dr. A l l e n at the Plymouth laboratory), and the animals were obtained from the plankton of the River Humber. Adult and young *Neomysis vulgaris* (J. V. Thompson) have been used largely and a few experiments were made with the copepod *Eurytemora hirundoides* (Lilljeborg). These form by far the most numerous members of the estuarine zooplankton and often almost pure collections may be made. Observations and a few experiments suggest that under laboratory conditions of illumination the copepods are in the main photopositive, and the adult mysids are mainly photonegative: the young mysids are intermediate in their reactions with perhaps a negative tendency. For further investigation on the present lines with these or any other zooplankton forms, a careful investigation of their tropisms would be helpful and probably necessary for the correct interpretation of the results.

I should like at this stage to express my thanks for the helpful discussions with, and encouragement given to me by, Professor H a r d y from the beginning of the work.

Exclusion Experiments 1934.

In these experiments it was desirable to find out whether, given the alternative, plankton animals under laboratory conditions showed any indication of avoiding dense regions of active phytoplankton. It is difficult with any readily prepared apparatus to arrange a system whereby zooplanktonts can have easy access to and from a dense phytoplankton culture and so the following attempt was made to overcome this difficulty. Equal numbers of animals were placed in pairs of similar tubes, each member of which was darkened in a certain manner. Thus in the first experiment made, five mysids were placed in each of two tubes (36″ × 1″) arranged horizontally with even and equal illumination along each; corresponding halves of each tube were darkened by a thick brown-paper outer cover fitting closely to the glass. It was at the time thought possible that in this way, owing to the action of the sunlight, photosynthesis might be set up in the illuminated part of the tube if plants were present and that the mysids in the tube would be able to move to and from such zones of active diatoms under any stimuli which might thereby be provided. In one member of each pair of tubes a strong culture of *Nitzschia closterium* was placed, whilst the other tube contained only diatom-free sea water. To ascertain the relative abundance of the mysids in the two parts of each tube, counts of those visible were made at equal intervals, and for any one set of observations, the totals were recorded for each tube. It must be noted here that the results for one set of observations on one pair of tubes may have relatively little significance; it is only on the results of a number of sets of observations that any confidence can be placed, and the significance of any differences in behaviour be determined.

The results obtained from these experiments are summarized in Table I. The experiments varied in their make-up but, as shown in the table, mainly consisted of two tubes arranged horizontally as described above. The first eleven such experiments were conducted for periods of one to three hours under varying conditions of illumination, and each experiment agreed in showing that the adult mysids showed themselves *less frequently* in the diatom tube (i.e., fewer appeared in the active diatom zone) than in the tube without diatoms. The strengths of the diatoms in the tubes varied somewhat, and at first no accurate counts were made, but in these eleven and the following two experiments (19 and 20 in Table I) the strengths of the diatom cultures were of the order of 1,000 cells per mm.^{3}. (It should be borne in mind that strengths of this order greatly exceed the maximum concentrations to be expected in the sea.) Two similar experiments with brackish water substituted for sea water showed in each more adult mysids visible in the diatom tube. Usually the animals, which have

Table I.

Showing the numbers of mysids visible during a number of observations in (a) control tubes and (b) tubes containing a culture of *N. closterium*. The experiments were made under several different conditions as enumerated below.

Reference No. of Experiment	Water used	Arrangement of tubes	Weather: Beaufort scale (see below)	No. of animals per tube	No. of observations made (all in daylight)	Total numbers of mysids seen in unshaded halves of the tubes (Expected frequency by chance)	Actual frequency: Diatom tube[1])	Actual frequency: Diatom-free tube
1	Sea water	Tubes 36″ × 1″ **horizontal** one half shaded	b-c	5	12	(30)	4	**18**
2			0	5	5	(12.5)	8	**12**
3			b-c	5	7	(17.5)	7†	**10**
4			0	3	8	(12)	0	**11**
5			0	3	7	(10.5)	4†	**9**
6			b	6	5	(15)	5	**19**
7			c	6	2	(6)	2	**12**
8			0	6	3	(9)	8†	**17†**
9			0	8	18	(72)	27	**43**
10			b	8	12	(48)	22	**46**
11			b	8	5	(20)	0†	**6†**
12			b	12 j.	13	(78)	58	**59†**
13		Tubes 18″ × 1″ **vertical** upper half shaded	b	6 j.	6	(18)	15†	**26†**
14			b	5 j.	16	(40)	25	**57**
15			b	5 j.	3	(7.5)	7	**11†**
16			b	10 j.	6	(30)	3	**22†**
17			b-c	6	13	(39)	49†	**65†**
18		lower half shaded	b-c	6	10	(30)	**8**	3
19	Brackish water	Tubes 36″ × 1″ **horizontal** one half shaded	0	18	11	(44)	**60**	44
20			0	15	?	(?)	*More*‡‡	Less‡‡

[1]) The approximate strength of diatom culture used in these experiments was of the order of 1,000 cells per mm.^{3}, with the exception of experiments 12, 14, 15, and 16, in which the cultures were only about one-half of this strength.

† = Deaths occurred
‡‡ = Detailed data lost
j. = Juvenile animals.

Beaufort scale
b = blue sky and sun
c = cloudy
0 = overcast.

been collected from brackish water, have been adapted before the experiment to the normal strength of sea water in which the diatoms are cultured; on these two occasions the diatom cultures were diluted with fresh water. It has been observed that in such conditions the photosynthetic activity of the diatoms is at a minimum, and so it seems reasonable to suppose that at such times the photonegative adult mysids might appear more in the illuminated areas of the diatom (and thus darker) tubes than in those of the diatom-free (and thus lighter)

tubes, in direct response to phototropism. On these grounds it has been decided to omit these two experiments from the total[1]). Two further experiments with adult mysids in paired vertical tubes, having (a) the lower halves darkened and (b) the upper halves darkened, showed respectively (a) most mysids in the diatom tube and (b) most in the control. Thus, out of thirteen sets of observations with adult mysids in sea water, in twelve the greater number was observed in the diatom-free tube. In addition five experiments (12 to 16) were made with young mysids of which all were in agreement with the majority of the adult data (for details, see Table I; in four of these experiments it should be noted that the diatom cultures were weaker than before). In several of the experiments with both young and adult mysids, deaths have occurred. These may have been due to a variety of reasons[2]), but the part played by high temperatures in the laboratory may have been important. (It was not possible to control the temperatures during the experiments and it was found particularly in the heat of the summer that the animals would only live for a very short time; for this reason experiments had to be discontinued owing to the very rapid death-rate.) Such observations in Table I have been marked with a dagger; deaths must have certainly altered the resulst to some extent but although more occurred in the diatom tubes than in the controls (see also p. 355) the distribution is such that they tended in some cases to increase the numbers visible and in others to decrease them in both types of tube.

In Table I other details concerning each experiment have been shown, but these will receive little discussion in the text. It is of interest to note, for instance, that if we separate, among the eleven experiments with adult mysids in horizontal tubes (normal sea water), those in which sunny conditions prevailed from those in which clouds, rain, etc., were prevalent, we find a rather higher percentage difference between the two tubes under the conditions b and b—c (Beaufort scale) than under c and 0. Under the stronger illumination the mysids were even less visible in the diatom tubes than when the illumination was reduced. Although such details must be of importance in any future investigation, it is felt now (as with many of the later experiments) that the differences between individual results cannot, for the greater part, be profitably discussed without further information (chemical analysis etc.). However, whilst I feel that the differences between the results obtained in the horizontal experiments and the vertical cannot properly be discussed at this stage, it may be of interest to mention certain differences involved in the two types of experiment. It should be realized that in the laboratory the larger plankton animals may be considered as relatively powerful swimmers; thus in the horizontal tubes the mysids are able to move *horizontally* to and from a region of photosynthesis, whilst such movements are probably rare if at all

[1]) With these two results compare also pp. 351, 354 and 356.

[2]) There seems to be little doubt that some of these have been due to the suggested "lethal" effects of strong diatom cultures (see also p. 353).

possible in relation to large phytoplankton patches in the sea (see also Hardy, 1935, p. 322). In the vertical tubes, on the other hand, movement is almost restricted to a vertical direction, and when the illuminated area is above, the conditions are more similar to those in the sea. The two types of experiment moreover may be used for segregating different types of reaction; in the horizontal experiments with both ends of the tube closed, the effects of gravity and the air supply must be similar along the length of the tube, but in the vertical tubes these effects may play a considerable part in the reactions involved[1]). For another difference between the two arrangements, see also footnote [2]) below.

The important point emerging from these eighteen sets of observations under different conditions is that in the greater number (seventeen) the animals inhabited the illuminated area less in the presence of diatoms than in the diatom-free medium. In two further experiments, when photosynthesis was at a minimum, the reverse was the case. It would appear that such activity, however interpreted on further analysis, would not be incompatible with the hypothesis of animal exclusion as expressed on p. 343 in the proposer's own words.

Exclusion Experiments 1936.

This spring (1936, the previous work being done in 1934) the experiments were continued with, as far as the limited time would allow, a more detailed analysis. The lethal experiments, to be described later but mainly performed earlier, had suggested the existence of an optimum diatom concentration. In order, if possible, to throw further light on this, a series of tubes containing different strengths of diatom cultures, and also diatom-free tubes, were arranged in place of the pairs of tubes used previously. The tubes containing the different diatom strengths will be referred to as 1,000 cell, 500 cell, 250 cell tubes etc., indicating that each contained cultures of *N. closterium* at strengths of 1,000, 500, 250, etc., cells per mm.^{3} respectively. The tubes were arranged sometimes horizontally and sometimes vertically[2]) and in some experiments the copepod *Eurytemora hirundoides* was

[1]) The reviewer of Prof. Hardy's publication (1935) in *Science Progress* (1936, p. 694) referred also to an aspect of the differences involved between the use of horizontal and vertical tubes and had erroneously considered the whole of the tubes to be vertical. They were, in fact, mainly horizontal.

[2]) The tubes referred to here and later in this paper (for brevity) as vertical, were not in fact strictly so. They were mounted on a bench, inclined towards the window at an angle of about 70° with the horizontal, illumination coming from the top as in truly vertical (outdoor) experiments. Thus, when the tubes were shaded at the bottom, the upper illuminated portion would show a light gradient (with directive effects) along its length, the lowest end of the gradient leading towards the shaded portion. It should be noted that in the horizontal tubes this relation does not exist; the direction of the light is at right angles to the length of the tube, the only directive effect along the length of the tube being in the shaded portion near to its junction with the illuminated portion. To a lesser degree this applies also to the truly vertical tubes.

used, young and adult mysids being used in the other experiments as before. These experiments have been valuable in producing results which are more suggestive than the earlier ones, but their greatest value may perhaps have been in revealing how inadequate the present methods have been for any other purpose than showing the existence of certain trends which deserve further analysis in the future.

In the text each set of observations will be considered only very broadly, the full details for each tube being given in Tables II, III, and IV.

Table II.

Showing the numbers of adult mysids visible in half-shaded tubes when in the presence of various strengths of diatom cultures. Sea water and 36″ × 1″ tubes have been used throughout the experiments.

Reference No. of Experiment	Arrangement of tubes	Weather: Beaufort scale	Numbers of animals in each tube	No. of observations made (all in daylight)	Numbers of animals seen in the unshaded halves of the diatom tubes and diatom-free tubes. (Strengths of diatom cultures shown in cells per mm.³) (Expected frequency by chance)	4,000 cells	2,000 cells	1,000 cells	500 cells	250 cells	Diatom-free tubes a.	Diatom-free tubes b.	Summarized Data Average numbers of animals seen in tubes containing more than 250 cells pr. mm.³	Summarized Data Average numbers of animals seen in tubes containing 250 cells pr. mm.³ and less
21	**Horizontal:** one	c	10	18	(90)	80?	39	53	74	86	65	–	61.5	**75.5**
22	half	c	10	7	(35)	–	10	12	15	11	21	6	12.3	**12.7**
23	shaded	c	10	22	(110)	–	82	26	32	59	34	32	**46.7**	41.7
	Vertical:													
24	lower half	c	10	10	(50)	–	12	16	25	40	26	25	17.7	**30.3**
25	shaded	c	10	8	(40)	–	17	8	13	16	16?	29	12.7	**20.3**

Beaufort scale as in Table I.
? = result doubtful owing to deaths in tube.

Experiment 21—23. Table II.

These were preliminary experiments with adult mysids in horizontal tubes arranged one above the other against the laboratory window (north aspect) so that the unshaded half of each tube was equally and evenly illuminated.

Experiment 21 suggests that a culture strength of 250 cells per mm.³ provided optimum conditions for the appearance of the animals in the illuminated area; on either side of this point the numbers visible decrease except for the result in the 4,000 cell tube. In this tube, nearly from the start, a constant number of four mysids was to be seen on each occasion; these became sluggish and one appeared to be dead. At the end of the experiment three were found to be dead although in the other tubes all were found to be active. It seems likely that the abnormal diatom density in this tube may have had an adverse effect on the activity of the mysids even to the extent of killing

some in the course of three hours (c.f. lethal experiments to be discussed later).

In Experiment 22 the 4,000 cell tube was discarded and an additional diatom-free tube was used. The results showed, for the diatom tubes, a maximum appearance in the 500 cell culture but there was a still higher number in one of the diatom-free tubes, the other one showing the minimum number of appearances (the existence of such a difference between similar tubes is a factor for serious consideration). Since these two tubes were at the top and bottom of the series (spatially) and might possibly (though it was thought improbable) have been differently illuminated, it was decided to reverse the whole series, the resulting observations having been regarded as Experiment 23. Then the numbers of the 2,000 cell tube remained consistently higher than in any other tube and, as in the 4,000 cell tube in the previous experiment, they became sluggish so that two of them remained persistently at the far end of the illuminated area: they had been in this higher strength of diatom culture from the beginning of Experiment 22. Apart from this the results were in agreement with those of Experiment 21, the maximum appearance being in the 250 cell tube. Though one mysid in each diatom tube at the end of the experiment was found to be very weak, as against none in the diatom-free tubes, this time there were no deaths.

Experiments 24—25, Table II.

Here vertical tubes with shaded lower halves were used. In Experiment 24 the maximum number of appearances was again in the 250 cell tube; in Experiment 25 the maximum number in the diatom tubes was in the 2,000 cell tube but this number was greatly exceeded by one of the diatom-free control tubes.

Table III.

Showing the numbers of young mysids visible in half-shaded tubes when in the presence of various strengths of diatom cultures. Sea water and 36″ × 1″ tubes have been used throughout the experiments.

Reference No. of Experiment	Arrangement of tubes	Weather: Beaufort scale	Numbers of animals in tube	No. of observations made (all in daylight)	Numbers of animals seen in the unshaded halves of the diatom tubes and the diatom-free tubes		
					(Expected chance frequency)	1,000 cells per mm.^{3}	Diatom-free tubes
26	**Vertical:** lower half shaded	b	10	7	(35)	**34**	29
27		b	11	9	(49.5)	**54**	42
28	**Vertical:** upper half shaded	b	10	8	(40)	35	**48**
29		b	11	6	(33)	40	**42**
30		b	10	12	(60)	47	**61**

N.B. Beaufort scale as in Table I.

Experiments 26—30, Table III.

These experiments were made with *young* mysids, and pairs of vertical tubes were used, one having a diatom strength of 1,000 cells per mm.^{3} and the other being a diatom-free tube. In Experiments 26 and 27 the lower halves of the tubes were shaded, and in 28 to 30 the upper halves. In the former two the greater number of appearances was in the diatom tube, and in the latter three in the diatom-free tubes.

Table IV.

Showing the numbers of *Eurytemora* visible in vertical tubes (lower half shaded) when in the presence of various strengths of diatom cultures. 18″ × 1″ tubes have been used throughout the experiments.

Reference No. of Experiments	Water used	Weather: Beaufort scale	Number of observations made (all in daylight)	Strength of diatom cultures (in cells per mm.^{3}) used in each tube and the relative visibility[1]) of the animals in each tube					Summarized Data. Average numbers of animals seen in tubes containing	
				(Expected frequency by chance)	1000 cells	500 cells	250 cells	control	more than 250 cells per mm.^{3}	250 cells per mm.^{3} and less
31	Brackish water	c	10	(50)	50	44	24	32	**47**	28
32	Sea water	c	10	(50)	34	74	71	74	54	**73**
33		c	7	(35)	28	26	54	33	27	**44**
34		c	8	(40)	13	49	96	70	31	**83**

[1]) In these experiments slightly differing numbers of animals have been used (as 10, 11, 9, etc.) and the relative visibilities represent the total numbers visible divided by the numbers in each tube and then multiplied by 10.

N.B. Beaufort scale as in Table I.

Experiments 31—34, Table IV.

These were made with the copepod *Eurytemora,* each experiment consisting of four vertical tubes: 1,000 cells, 500 cells, and 250 cells per mm.^{3} diatom cultures and one diatom-free tube with, in each set, the lower halves shaded. In Experiment 31 brackish water was used and the highest number of appearances was in the 1,000 cell tube (c.f. the brackish-water mysid Experiments 19 and 20). Experiments 32 to 34 were in sea water and showed a minimal appearance in the 1,000 cell tubes; in two a maximum in the 250 cell tube and in one an almost even appearance in the 500 cell, 250 cell, and diatom-free tubes.

There are considerable differences in the behaviour of the animals in the different experiments, due possibly to such causes as their differing states of phototropic reactions at the times of the experiment, shock effects, etc., (see, for example, C l a r k e, 1930), conditions which should be investigated more fully in future work. Yet the results obtained appear to indicate, in spite of such masking effects, certain trends in the behaviour of the animals in relation to the diatom

cultures. In each of the tables are compared the average numbers of appearances in the higher diatom tubes, i.e., those with more than 250 cells per mm.^{3}, with those in the 250 cell and the diatom-free tubes. Omitting the brackish water experiments we find that for adult mysids (Expts. 21—25) and *Eurytemora* (Expts. 32—34), in seven out of eight experiments, the numbers of appearances in the lower diatom cultures exceeded those in the higher diatom strengths, the only exception being possibly explained by the sluggish behaviour of the mysids (horizontal tube) apparently induced by the high 2,000 cell cultures.

Certain other experiments on similar lines have also been made, and these will be considered before dealing with the young mysid results (Expts. 26—30). Three sets of observations have been made comparing the activities of old and young mysids in similar (strong) diatom solutions. The general results of all our work would show the young mysids under laboratory conditions to be less photonegative than the old ones, and these three experiments in addition show that in strong diatom cultures they are to be found to a relatively greater degree than are the adults in the upper illuminated portions of vertical tubes which are shaded below, and that also when no shade is provided they are still to be found in greater numbers in the upper parts of the tube than are the old animals (Table V.).

Table V.

Showing the percentage of young and adult mysids respectively observed in the upper half of 36″ × 1″ tubes (vertical) in cultures of about 1,000 cells per mm.^{3} in sea water.

Weather: Beaufort scale	Use of shade	No. of observations	Percentage Visibility	
			Adults	Young
c	Lower half	9	13.3	**54.0**
b	None	8	12.5	**53.8**
c	,,	9	25.0	**53.0**

N.B. Beaufort scale as in Table I.

The whole of the results (1934 and 1936) may now be reconsidered to some extent, the pairs of averaged results quoted for 1936 being comparable with the pairs obtained in 1934, in that for each set the numbers of appearances in high diatom tubes are compared with those in tubes with fewer or no diatoms. Added reason for considering the two sets of results (1934 and 1936) as being comparable is found in the fact that in 1936 similar pairs of observations would be obtained if instead of comparing the appearances (averaged) in the higher and the lower tubes, we compared the appearances in the 1,000 cell tubes with those in the diatom-free tubes as in 1934. In all, thirty-one experiments were made to test the reactions of the animals to the presence of actively photosynthetic diatoms, and twenty-seven of these (including the 1936 young mysid results) would suggest a general

tendency to avoid more the illuminated areas of diatom-containing water than the similarly illuminated areas of water with fewer diatoms or none. These twenty-seven experiments (all in sea water) comprise sixteen out of the eighteen experiments with adult mysids, eight out of ten with young ones and each of the three experiments with copepods. If all the experiments were otherwise comparable (or if the whole had been suitably designed) it would be essential to compare the different types of reaction found in the vertical tubes with those in the horizontal; under the conditions of the experiments we cannot rely greatly on such differences as may appear to exist. Any such differences might be due to the introduction in the vertical experiments of the directional effects of light along the whole length of the tube and (or) the effects of gravity. However this may be, it would appear that the young mysid experiments (all but one of which were vertical) should at this stage be considered apart from the others. Table V shows how the young mysids are to be found much higher in the tubes in strong diatom cultures (and also from general observation, in diatom-free water) than are the older ones. Comparing this result with Table III we see that there, in each case, the young mysids are higher in the tubes in the diatom cultures than in the diatom-free tubes, irrespective of the shading of the tubes. The vertical experiments with young mysids made in 1934 (13—16) would not be in opposition to this interpretation, although at first sight the young mysid observations as a whole appear to be in agreement with the adult mysid experiments. It seems that the reactions of the young mysids to the presence of strong diatom cultures may differ from those of the older ones. In relation to these observations it is interesting to note that Hardy (1935 and 1936) has drawn attention in his argument to the fact that the younger stages of the zooplankton tend to be found at higher levels of the water than the older ones, in particular mentioning Wimpenny's observation concerning the presence of a larger proportion of young zooplanktonts in the centre of the phytoplankton patches than was to be found outside the patches (1935: see also Savage and Wimpenny, 1936). It seems that the young mysid results, whilst in some ways appearing exceptional, would, like those obtained with older mysids and the copepods, not be in conflict with the general hypothesis of animal exclusion.

"Lethal" Experiments.

These experiments were devised to test the length of life of plankton animals in cultures of diatoms of different strengths. Various numbers of animals have been used in the course of this part of the work and their length of life or "viability" has been computed in animal-days, such that if (say) 4 mysids lived in a culture for three days and three of them for a further three days, then the viability up to that date would be said to have been 21 mysid-days. The results of nine experiments (including one on *Eurytemora*) are shown in Table VI. In many

Table VI.

Showing the length of life of plankton animals in cultures of different diatom densities. Adult mysids were used in all the experiments excepting the first *(Eurytemora.)*.

No. of experiment	Length of life in cultures of density ranges shown below					
	0 – 25	25 – 100	100 – 250	250 – 500	500 – 1000	over 1000[1])
1†	20[2]	**47[3]**	38[4]	31[1]	–	–
2†	19[2]	**23[2]**	21[3]	17[2]	20[1]	20[1]
3†	11[1]	22[1]	**29[1]**	12[1]	**33[1]**	6[1]
4	10[2]	**14[2]**	11[1]	4[1]	–	–
5	3[2]	**8[3]**	6[3]	7[1]	7[1]	–
6	5[1]	**7[3]**	6[1]	6[1]	5[1]	–
7‡	66[1]	**67[3]**	66[2]	62[1]	61[1]	–
8	6[1]	8[1]	5[1]	**15[1]**	10[1]	6[2]
9	4[1]	**12[1]**	2[1]	–	–	–

[1]) Numbers in cells per mm.[3].
† Estimates of the density of diatom cultures in these experiments were only approximate. The relative proportions were accurate.
‡ Brackish water used.
The indices denote, for any density range, the number of results on which the mean figure shown has been based.

ways the methods used have been very crude; the short length of life, even at the optimum range, suggests that the presence of other ill effects than the hypothetical effects of diatoms was playing too large a part (the possible ill effects of high temperatures have already been mentioned on p. 347). Again, some experiments had to be discontinued long before all had died, owing to the remarkable appetites of the animals (see next section). These were capable of reducing the diatoms so rapidly on occasions that the desired range of cultures might be entirely disorganized. It must also be noted that many experiments have included cultures of diatoms of strengths greatly exceeding anything likely to be found in the sea.

In spite of these points, there is one feature of interest. In all but one of the experiments a maximum length of life is to be observed in an intermediate and apparently optimum strength of diatom culture[1]), the optimum being apparently between the grades of 25 and 100 cells per mm.[3], for the particular conditions of the experiments in which given numbers of animals were enclosed in *limited* volumes of the culture (a state not readily to be matched in the sea)[2]).

[1]) In relation to previous experiments (p. 347) it is interesting to note the absence of any appreciable difference in one experiment (7) in which brackish water was used.

[2]) Variations in the optimum of these and other experiments might well be due to variations, certainly present, in the photosynthetic activity of the diatom cultures used.

Without much more data concerning the chemistry of the cultures and adequate controlling of them and the environment, it would be dangerous to go further than the broad deduction regarding the presence of an optimum concentration of diatoms *(for a given density of animals)*, on either side of which an apparently harmful effect may be observed. (It seems worthy of note here that both in the earlier and later "exclusion" experiments the greater number of deaths occurred in the denser diatom tubes, an intermediate number in the diatom-free water, and that there were still fewer deaths in the 250 cell tubes.) Such a deduction would not, it seems, be antagonistic to the theory of animal exclusion, and indeed the evidence produced may not be unrelated to the fact that H a r d y (1935) found in the South Georgia plankton survey that the zooplankton organisms tended to occur in larger numbers in water of intermediate phytoplankton concentration, both when measured by numbers of plant cells and by consideration of phosphate values (*loc. cit.* Tables LIII and LIV).

Feeding Experiments.

In the spring and summer of 1934, forty-one experiments were made to test the feeding *potentialities* of plankton animals as a preliminary to investigating their *actual requirements*. Whilst it is hoped to continue these experiments, it may be of value to summarize here the results up to date, since they bear a relation to the recent work of H a r v e y (1934, 1935) and H a r d y (1935) on the zoo-phyto-plankton inter-relations under natural conditions in the sea.

Criticisms applicable to H e n s e n's work on the feeding of plankton animals (see D a k i n, 1908) suggested to the writer that the best results would be obtained only if (at least in the earlier stages of the work) pure samples of zooplankton should be used. Pure samples of known numbers of the mysid *Neomysis vulgaris* or the copepod *Eurytemora hirundoides* were placed in cultures of the diatom *Nitzschia closterium* of various strengths (estimated by counts with a Bürker haemocytometer). They were then left for various periods when subsequent counts would reveal the numbers eaten and hence the rate of feeding. Small cultures (usually about 100 c.c.) had necessarily to be used in order to ensure that a measurable difference in the number of cells per mm.^{3} would be obtained between the beginning and the end of the experiment.

The experiments were conducted in the dark to minimize the multiplication of the diatoms. Controls, however, showed that even in the darkness, a fresh culture of diatoms may continue to divide to an appreciable extent so that the results obtained are mainly minimal[1]).

The feeding of *Neomysis* was tested by twenty-five experiments, from one to eight mysids being used in any one experiment and the densities of the diatoms varying from 53 to 2,875 cells per mm.^{3}. The

[1]) Indeed, in Expt. 4, Table VIII, we find a negative rate of feeding which must be due in part at least to this cause.

Table VII.

Showing the details of the experiments on the rates of feeding of mysids under various conditions. Experiments 1 to 8 were made in the spring on large mysids and 9 to 25 in the summer on smaller ones. With the exception of Experiment 22 (5 hr.) the experiments were all conducted for about 24 hours.

No. of Expt.	No. of Animals	Original No. of cells pr. mm.^{3}	No. of cells pr. mm.^{3} eaten	Cells eaten per animal per hour	Notes
1.	1	975	825	5.6 $\times 10^6$	Brackish water
2.	1	1050	950	6.5 $\times 10^6$	
3.	2	1075	975	3.3 $\times 10^6$	
4.	3	1050	125	0.3 $\times 10^6$	
5.	4	775	725	1.2 $\times 10^6$	
6.	2	2875	500	1.3 $\times 10^6$	
7.	2	2175	275	0.7 $\times 10^6$	
8.	2	1750	100	0.3 $\times 10^6$	
Control to Expts. 6—8		1725	—700		
9.	1	2402	472	2.4 $\times 10^6$	
10.	1	2120	500	2.2 $\times 10^6$	
11.	1	2184	116	0.5 $\times 10^6$	First day
12.	1	2068	52	0.2 $\times 10^6$	Second day
13.	1	1408	210	1.2 $\times 10^6$	First day
14.	1	1198	96	0.4 $\times 10^6$	Second day
15.	1	1430	146	0.7 $\times 10^6$	
16.	4	2114	854	0.8 $\times 10^6$	
17.	2	2114	556	0.9 $\times 10^6$	First day
18.	2	1558	136	0.4 $\times 10^6$	Second day
19.	1	2114	312	1.2 $\times 10^6$	
20.	1	2114	440	1.5 $\times 10^6$	First day
21.	1	1674	82	0.4 $\times 10^6$	Second day
22.	8	2114	462	0.9 $\times 10^6$	
23.	1	356	19	0.07 $\times 10^6$	
24.	1	71	4	0.02 $\times 10^6$	
25.	1	53	8	0.03 $\times 10^6$	

details are shown in Table VII and the different types of experiment may be subdivided as follows.

(1) Eight experiments were made in the spring with adult mysids, and a further seventeen were made in the summer when rather smaller (but not juvenile) musids were the largest forms available[1]). Whilst

[1]) Of the eight spring experiments, brackish water was used in five and in the other three, sea water: on p. 346 we have already referred to the reduced photosynthesis of the diatoms in brackish water, and it is interesting to note the considerably higher rates of feeding in this water than in the normal. It would appear that this would not be a real difference but an apparent one (arising in the counting method) due to the residual powers of reproduction of diatom cultures in the sea water when placed in the dark.

the data are too scanty for any definite conclusions to be drawn, certain trends in the results are very suggestive. Thus we see that in the spring series (brackish water) one mysid was feeding at the rate of about 6×10^6 cells per mysid per hour (mean of two experiments) whilst two, three, and four animals, in the same volume and similar densities of the culture (about 1,000 cells per mm.^{3}) only fed at the rate of ca. $1{\cdot}5 \times 10^6$ cells per mysid per hour (mean of three results). Again, in the summer, five experiments using only one mysid showed an average feeding rate of $1{\cdot}5 \times 10^6$ cells per hour, whilst in three experiments with more than one mysid (two, four, and eight) in similar volumes of similar (2,000 cell) cultures, the animals were feeding at a rate of under $1{\cdot}0 \times 10^6$ cells per mysid per hour. All but one of these experiments were conducted for about twenty-four hours.

(2) Thirteen experiments using only one mysid in different diatom cultures gave the following rates of feeding in the summer.

Density of Diatoms	Feeding rate per mysid per hour	No. of Experiments
2,000 cells and over	$1{\cdot}3 \times 10^6$	6
1,000 to 2,000 cells	$0{\cdot}7 \times 10^6$	4
Less than 500 cells	$0{\cdot}04 \times 10^6$	3

(3) During four experiments with single cultures in each of which one mysid was allowed to feed for two days, it was found that the feeding rates on the first day were 0·5, 1·2, 0·9, and 1·5, $\times 10^6$ cells per mysid per hour and that on the second day these rates were reduced to 0·2, 0·4, 0·4, and 0·4, $\times 10^6$ cells per hour respectively. It will be realized that owing to the feeding on the first day the density of the culture would be reduced by the beginning of the second day; on the results of the experiments outlined in the previous paragraph we might expect a slightly reduced feeding rate for this reason, but in these experiments the feeding rates were each reduced by more than fifty per cent. whereas the densities of the diatoms were never reduced by more than twenty-five per cent.[1]).

(4) Thirteen experiments (Table VIII) with the copepods showed that on the average each was capable of consuming some 5,000 cells per hour (in dense cultures), the maximum record being 23,000 cells per hour and the variation under different conditions being considerable. It was found that when the feeding was continued for two consecutive days, the rate of feeding on the second day was considerably reduced, and there was some evidence that when the experiments were conducted for one day in similar densities of diatoms (about 1,000 to 1,500 cells per mm.^{3}) the rates of feeding were somewhat lower when large numbers of copepods were used than when the numbers were smaller.

[1]) It may be of interest to note that the mysids, which are normally supposed to be filter feeders, will (particularly if not supplied with fine suspended food, e.g., diatoms) pounce upon copepods and eat them. Mysids kept during this work have also been seen carrying about dead mysids and amphipods of nearly their own size and apparently "chewing" them.

Table VIII.

Showing the details of the experiments on the rates of feeding of *Eurytemora* under various conditions. The experiments were all continued for about 24 hours.

No. of Expt.	No. of animals	Original No. of cells per mm.^{3}	No. of cells per mm.^{3} eaten	Cells eaten per animal per hour	
1.	150	1625	650	23,000	First day
1 a.	150	975	200	6,000	Second day
2.	600	1150	775	7,000	First day
2 a.	600	375	250	2,000	Second day
3.	900	1550	1275	8,000	First day
3 a.	900	275	212	1,000	Second day
4.	70	1200	—150		
5.	85	1225	150	8,000	
6.	160	1288	138	4,000	
7.	225	1263	238	5,000	
8.	450	1150	350	3,000	
9.	800	1150	625	3,000	
10.	1050	1057	813	3,000	
Control to Expts. 4—10		1125	—100		

These experiments with copepods would appear to offer some evidence in support of the tendencies shown by the previous ones using mysids, and on the basis of these results it has seemed not unreasonable to put forward very tentatively the following hypotheses which could form a basis for future experimental work.

(1) Given similar food strengths the rates of feeding may be found to vary inversely with the number of feeders.

(2) Given various food strengths, the rates of feeding may be found to vary directly with the amount of food available.

(3) Given a very rich food medium, the rate of feeding may be found to decrease with the progress of time.

(4) From (2) and from the fact that the strengths of the diatom cultures used in these experiments are mainly greatly in excess of those found in the sea, we can deduce that the copepods and mysids used tend to feed much in excess of their requirements when the food is abundant. The last two points would appear to be in agreement with the deductions of Harvey (1935) made from observations of the conditions actually occurring in the sea[1]).

Discussion.

Any conclusions derived from the present experiments must necessarily be very tentative, but a certain amount of analysis may

[1]) It is important to note also that Savage and Wimpenny (1936, p. 42) found "that the percentage of feeding copepods rises with the amount of diatom food available."

be instructive. The experiments on the feeding rates of *Neomysis* and *Eurytemora* do not seem to warrant discussion at this stage, though they may be of interest in showing (for the first time)[1]) information concerning the possible rates of feeding (almost certainly not maximal) which can be obtained for short periods at least, when food is abundant and perhaps even excessive. Also certain tendencies can be shown which may warrant further investigation. Such information seems necessary before we can assess the respective roles played by "grazing" (Harvey) and "animal exclusion" (Hardy).

When we consider the so-called "lethal" experiments we find that there is some evidence of ill effects associated with dense growths of diatoms on the length of life of the animals inhabiting them. This might be a purely chemical lethal effect, but against this must be borne in mind the possibility that death under these circumstances might also be the results of automatic over-feeding. The heavier death-rate on the lower side of the apparently optimal conditions, i.e. under mainly diatom-free conditions, may well be due to an insufficiency of food. Hardy (1935) has also pointed out that the scarcity of zooplankton in those areas where the phytoplankton is least abundant may be due to the absence of the necessary quantity of food. In favour of a chemical effect due perhaps to photosynthetic activity (pH, Oxygen, Carbon-dioxide, phosphates, etc. either in excess or in deficiency at either end of the series), there has been some slight evidence that the death-rate in dense diatom cultures *in darkness* (i.e., with little if any photosynthesis) is lower than in daylight, but this would need further investigation.

The "exclusion" experiments offer little doubt that we must not interpret the results as necessarily indicating a simple reaction by the animals to the effects of photosynthesis in the illuminated areas of the tubes. Such an interpretation might be correct but this could only be determined further by means of chemical analysis: we must bear in mind the many other possible factors. Nevertheless, whether it is a simple reaction or a complex chain of cause and effect, the photo-tropisms shown by all the animals *in the full light of the laboratory* would lead us to expect a greater visibility in the darker diatom cultures than in the weaker cultures and the controls. In general this was only evident when brackish water was used, i.e., *when photo-synthesis was at a minimum*, whereas in the sea water with more or less active phytoplankton the animals *avoided* the light most in the stronger and consequently *darker* cultures.

Again, whilst at this stage, owing to the very crude nature of the experiments, little attention has been paid to apparent anomalies in the reactions; in further work it would appear necessary to pay fuller

[1]) Dr. G. L. Clarke has been making qualitative experiments on the feeding of *Calanus finmarchicus* at Woods Hole (1935 and in press) and Mr. H. W. Harvey (private communication) has informed me that he is making some quantitative experiments on the feeding rates of *Calanus* at Plymouth. I am indebted to both workers for permission to see this unpublished information.

attention to these, and indeed to investigate the reactions of individuals in addition to those of groups of animals. Clarke (1932) has shown how important it is to consider the activities of the individual as distinct from those of the group, whilst the experiments of Allee and many other workers (admirably summarized by Allee, 1931 and 1934) have shown how very important in any experimental work may be the variations in the relations between the number of animals used (the size of the group) and the culture medium (the size and constitution of the immediate environment). In any future work these factors would need serious consideration.

There is every reason to believe that the reactions shown would be the results of a complex inter-relationship of several factors of which a modification of phototropism by the changes in the environment at this stage seems to be the most probable. For example, it may be that in the presence of strong phytoplankton cultures the original photopositive reaction may become less photopositive (or even negative) whilst originally photonegative animals may become even more so[1]). Certain differences between the horizontal and vertical results suggest that the parts played by geotropism and aerotropism may not be insignificant and the possibility of inter-reaction between all these tropisms must not be forgotten. Other factors may also play a part, and for a complete understanding of phyto-zooplankton inter-relationships the respective roles of the different factors need to be assessed. When using the very elementary methods of experiment adopted so far, the segregation of the respective effects of different factors appears to be a formidable task. If this work is to be repeated and checked (as we hope may be done later) different methods must be adopted. Fisher (1936) has pointed out that the unravelling of the effect of several factors need not necessarily make for greater complexity in the work. If suitably arranged (by replication and random sorting) the experiments may be made at once under several conditions to yield the maximum information concerning any one variable and also to segregate the parts played by the different variables and the possible interactions between them. For instance, an experiment of a certain size may be so arranged as to provide as much information about each of the factors and their interactions as it would for any one of them if arranged only with that factor in view, i.e., by standardizing the other variables (for further detail see Fisher, 1936, Chapter VI).

At this stage it seems important only to emphasize the facts that have been observed, i.e., the reaction of certain plankton animals in the laboratory in ways which do not appear to be antagonistic to, and may appear to offer support for, the hypothesis of the exclusion of animals from dense zones of active phytoplankton in the sea.

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[1]) It will be remembered that Clarke (1932) found that *Daphnia* exhibited a strong positive phototropism in a dilute culture medium but that "when the culture medium is fresh and rich most of the animals are primarily negative to light."

Summary.

1. Eighty-six elementary laboratory experiments have been made regarding the inter-relationships between marine zoo- and phytoplankton in reference to the work of Harvey (1934 and 1935) and Hardy (1935 and 1936). They were designed to ascertain:—

(a) whether any avoidance of dense cultures of active phytoplankton by zooplankton could be shown;

(b) whether, if avoidance was impossible, any particular effects on the zooplankton could be observed; and to make

(c) a preliminary investigation of the possible (though by no means necessary or optimal) rates of feeding of the zooplankton on the phytoplankton.

2. The phytoplankton was represented by almost pure cultures of the diatom *Nitzschia closterium* and the zooplankton by either *Neomysis vulgaris* or *Eurytemora hirundoides*.

3. The crudity of the experiments is recognized and discussed; suggestions are made for improvements in future work.

4. In spite of the crudities the following broad conclusions can be drawn from the experiments of types (a), (b) and (c) in (1).

(a) In sea water, under various conditions, zooplanktonts tended to avoid light in the presence of strong diatom cultures more than in weaker cultures or in diatom-free tubes. In brackish water where the diatoms were not actively photosynthetic the reactions were reversed. Indications of other trends are discussed.

(b) Animals lived for a relatively shorter time in the denser *Nitzschia* cultures and in diatom-free water than in an apparently optimum range of culture of 25—100 cells per mm.^{3}.

(c) *Neomysis* consumed an average of over 1,000,000 (maximum 6,500,000) cells of *Nitzschia* per hour in very dense cultures and *Eurytemora* over 5,000 (maximum 23,000) cells per hour. Hypotheses for future experimental testing have been tentatively put forward.

5. On the whole it is concluded that the results so far provide evidence that at least is not incompatible with the hypothesis of Animal Exclusion as proposed by Hardy.

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A Modified Measuring Board.

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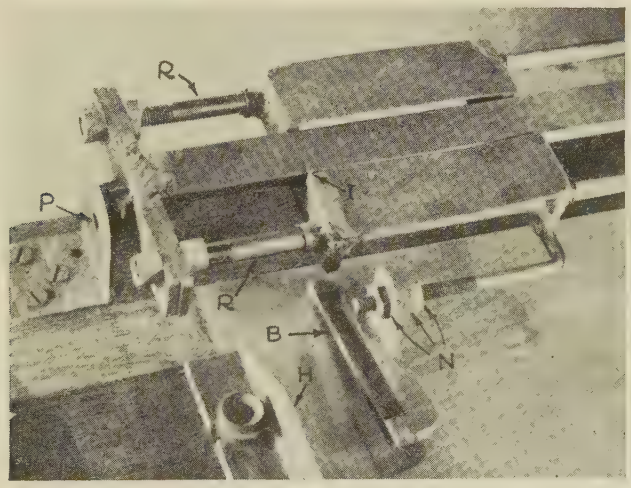
VARIOUS investigators have devised measuring boards which permit both speed and accuracy in measuring large numbers of small fish such as herring or pilchards. In the best of these, inaccuracies due to parallax are avoided by the use of mirrors placed parallel to the scale. It has been found, however, by three investigators in this laboratory that considerable eye strain is involved in reading



the scale while keeping a fine thread in alignment with its own image in the mirror and the end point on the fish. With the help of Mr. L. Quickenden a simple board has been devised which loses nothing in speed or accuracy of use but which does away with unnecessary eye strain. The essential features of the board are: (1) pivots (P) at both ends of the millimetre scale; (2) two smooth rods (R) parallel to the scale which carry the bearings supporting the pointer (B) and indicator (I). A minor feature is the arrangement of nuts (N) for adjusting the position and angle of the pointer. With this board parallax is avoided by having the indicator within a fraction of a millimetre of the scale and having the pivots to bring the pointer in actual contact with the fish. When the equipment has been adjusted to the proper zero any fish to be measured is placed parallel to the scale with its snout against the head plate (H) and the distance from the snout to any desired end-point touched by B may be read from the scale opposite the indicator.

Reviews.

B. Schulz. "Die hydrographische Lage im Kattegat im August 1931." Ann. d. Hydr., usw. LXIV. Jahrg., H. VI, S. 234—242, Taf. 37—44. Berlin, 1936.

H. Thorade. "Strombeobachtungen am Nordausgange des Kattegats." Ibid. S. 243—253, Taf. 45—49.

During the period August 6th to 21st, 1931, an international hydrographical investigation was carried out in the Kattegat, with Denmark, Finland, Germany, and Sweden co-operating. From the 10th to the 17th observations were made continuously from five ships at fixed stations in the southern part of the Kattegat. Before and after these observations cruises were made by the five ships in the Kattegat, the Sound and the Belts, and in the western part of the Baltic with observations at some fifty stations. The material collected — especially that from the fixed stations — has been treated in several publications.

In the papers under review B. Schulz deals with the hydrographical conditions before and after the observations at the fixed stations, and H. Thorade with current measurements from the German research vessel "Poseidon" on August 19th, 1931, at four stations in a section across the northern Kattegat at about 57°30′ N. Lat.

It is clearly seen from the papers of B. Schulz and H. Thorade — as well as from other publications on the investigations — that the hydrographical conditions in the Kattegat are more complicated than hitherto imagined. The supposition frequently made of an upper and a lower water layer moving in a northerly and a southerly direction respectively may be considered as a rough approximation only to the real movement of different water bodies in different directions.

In his paper B. Schulz has given a detailed analysis of the particularities of the different water masses met with in the Kattegat. For the description 55 diagrams are drawn up showing, for the times immediately before and after the observations at the fixed stations, 1) the horizontal and vertical distribution of temperature, salinity, and density; 2) the connexion between salinity and temperature, and between salinity and content of oxygen for different bodies of water; and 3) the horizontal distribution of different water bodies. There are also diagrams showing the variation of the temperature and the salinity at the "Poseidon" station between August 10th and 17th at different depths.

Three different water layers could be distinguished, namely: 1) the upper layer with low salinity and high temperature; 2) the intermediate

layer situated below the transition sheet ("Sprungschicht"); and 3) the lower layer.

The lower water layer could be divided into three characteristic water bodies situated, at the beginning of the investigations, in the northern, middle, and southern part of the Kattegat. During the period from August 8th to 18th the southernmost of these water bodies disappeared almost completely from the Kattegat through the Belts. The northern and middle water bodies extended somewhat irregularly in a southerly direction.

The intermediate water layer from 12 to 32 m. in depth could be divided into two characteristic water bodies extending, during the period in question, mainly in a southerly direction.

The upper layer was found to be of a more complicated nature than the intermediate and the lower ones. It was found that water of relatively high density at the surface was correlated with water of relatively low density at 20 m. depth and *vice versa.* The author remarks that this is in accordance with the rule deduced by v. Schubert from the observations at the "Poseidon's" fixed station between August 10th and 17th that the surface salinity and the depth of the transition sheet are positively correlated.

The weather conditions during the period in question, from the 6th to the 20th, were rather variable but no strong winds of a force greater than 6 Beaufort occurred.

The current measurements from the northern part of the Kattegat treated by H. Thorade were carried out at the four fixed stations over a period of some ten hours by means of three Rauschelbach current-meters. Two of the current-meters were placed amidships and used for recording the currents at various depths, in most cases differing two metres from each other. The third current-meter was placed astern and constantly used at 10 m. depth to provide a control for the influence of the movements of the ship on the records of the first two current-meters. The time used for the determination of the current at a single depth was two minutes. The analysis of the current measurements showed, however, that the control of the influence of the movements of the ship was not an effective one. Furthermore it was found that two minutes did not suffice for a current measurement, but that at least five minutes are required for the determination of the current at any one depth.

The difficulties in calculating the movement of the water from the observations were overcome by averaging the results from depths at suitable intervals. The results given in tables and graphs in the paper are discussed and compared with the movement of the water that could be expected on account of the variations in the sea level and on account of the internal fields of force in the sea. It is strongly emphasized by the author that the calculation of the movement could be carried out to a rough approximation only. Neglect of the internal friction and the supposition that the movement of the water was stationary during the period of observations, are mentioned as sources of uncertainty.

It was found, however, that the observed and the calculated water movements are so far in accordance that one may be justified in taking the results obtained as mainly representative of the water movement in the northern Kattegat at the time in question. As characteristic of the movement it may be mentioned that the current at the eastern station in the deep channel on the Swedish coast was north-going from the surface to a depth of 10 m., south-going from 12 to 50 m., and north-going from

52 to 66 m., and that the current on the western slope of the deep channel was found to run towards directions between S. and W. at all depths, whereas the current in the western part of the section some 7 miles from the Danish coast was north-going in the upper layers and south-going in the lower layers.

It is stated by the author that the water movement as found may be generally representative of the water movement over a longer period, but that simultaneous current measurements from more, e.g., four ships, are necessary to secure a real understanding of the water movements in the northern Kattegat.

J. P. Jacobsen.

J. N. Carruthers. "The Flow of Water through the Straits of Dover as gauged by continuous Current-Water Observations at the Varne Lightvessel (50°56′ N — 1°17′E). Part II. Second Report on Results obtained." Min. of Agric. and Fish., Fish. Invest. 1935. Ser. II, Vol. XIV, No. 4, London, 1935.

Auf dem in der Strasse von Dover gelegenen Varne-Feuerschiff wird seit 1925 mit dem Reststrommesser von Carruthers (vergl. Journ. du Conseil I, 1926, pp. 127—139) der Reststrom in 6 Faden Tiefe beobachtet und seit Juni 1926 regelmässig ausgewertet. Die bis Januar 1928 gewonnenen Beobachtungen sind in Teil I der vorliegenden Veröffentlichung behandelt (vergl. Journ. du Conseil IV, 1929, pp. 234—236), in Teil II sind die seitdem bis April 1935 gesammelten Beobachtungen mitgeteilt und diskutiert. Die weiterhin gesammelten Beobachtungen werden in monatlichen Zusammenfassungen im *Bulletin Hydrographique* veröffentlicht werden. Das benutzte Instrument bleibt in der Regel drei volle Mondtage unten, die erzielten Beobachtungen sind also mittlere Werte des Reststromes für diesen Zeitraum.

Die nunmehr bereits über acht Jahre umfassende veröffentlichte Beobachtungsreihe gestattet eine sicherere Feststellung von Extrem- und Mittelwerten als sie bisher möglich war. Der stärkste Reststrom in die Nordsee hinein wurde beobachtet vom 10.—13. Januar 1930 mit 21·0 sm./Tag in Richtung N. 50°E., der nächst starke Strom vom 17.—21. September 1930 mit 17·2 sm./Tag nach N. 48°E. Der stärkste Reststrom kanalwärts wurde vom 7. bis 10. Februar 1930 festgestellt mit 12·9 sm./Tag nach S.51°W. Der höchste Monatsmittelwert des nordseewärts gerichteten Reststromes stellte sich heraus für Dezember 1929 mit 11·4 sm./Tag nach N. 49°E., im Februar 1932 war er mit 3·7 sm./Tag am stärksten kanalwärts gerichtet (S. 75°W.). Im Mittel des ganzen Beobachtungszeitraumes ist der Strom in jedem Monat in die Nordsee gerichtet, am stärksten im November mit 4·1 sm./Tag; es folgen dann mit abnehmender Stärke Januar, Oktober, Dezember, August, Juli, Mai, März, April, September, Juni und Februar. Der Februar weist den schwächsten mittleren Reststrom auf mit 1·9 sm./Tag. Bei jahreszeitlicher Mittelbildung stellt sich heraus, dass der grösste Reststrom im Herbst auftritt; er ist mit 3·5 sm./Tag nach N. 25°E. gerichtet, in den übrigen Jahreszeiten ist der Reststrom 3·0 bis 3·1 sm./Tag stark und ist nach N. 15° bis 23°E. gerichtet. Dem entspricht, dass die 35 $^0/_{00}$—Isohaline im November, Dezember und Januar am weitesten in die Nordsee vordringt.

Betrachtet man endlich die Mittel für die Kalenderjahre, so bewegen sich die mittleren Restströme zwischen 3·9 sm./Tag nach N. 7°E. im Jahre 1934 und 2·9 sm./Tag nach N. 8°W. im Jahre 1933. Auffallend ist, dass die Richtung des mittleren Reststromes im Laufe der acht Jahre eine immer

mehr abnehmende östliche Komponente aufweist, von N. 40°E. im Jahre 1927 hat sie sich auf N. 7°E. im Jahre 1934 geändert. Das Gesamtmittel der 8 Jahre von 1927 bis 1934 ist mit 3·3 sm./Tag nach N. 20°E. gerichtet.

Der Vergleich der Messungen des Reststromes mit denen des Windes hat noch nicht die Aufstellung einer exakten Beziehung ermöglicht, wohl aber lässt sich aus den Windbeobachtungen an Bord oder in Dungeness schliessen, ob der Reststrom kanal- oder nordseewärts gerichtet ist.

Da die Möglichkeit besteht, dass das hölzerne Varne-Feuerschiff durch ein eisernes ersetzt werden wird, wird sich vielleicht die Notwendigkeit ergeben, die Beobachtungen mit dem Reststrommesser später in grösserer Tiefe anzustellen, um eine Einwirkung des eisernen Schiffes auf den Magneten des Strommessers auszuschalten. Dies machte die Untersuchung der Frage notwendig, in welcher Beziehung die dann in etwa $12^1/_2$ Faden Tiefe zu gewinnenden Beobachtungen zu den aus 6 Faden Tiefe stehen. Hierfür wurden die 1911—1913 und 1922—23 mit dem Jacobsen-Strommesser in verschiedenen Tiefen gewonnenen Beobachtungen herangezogen. Weitere Versuche wurden vom 11. VII. bis 5. VIII. 1931 mit zwei Reststrommessern in 6 Faden und $12^1/_2$ Faden Tiefe ausgeführt. Als Mittelwerte der Restströme in beiden Tiefen wurden gefunden 4·3 sm./Tag nach N. 22° E. und 4·1 sm./Tag nach N. 43° E. Als Ergebnis der ganzen Untersuchung über diese Frage wird festgestellt, dass die Reststrommessungen auch in $12^1/_2$ Faden Tiefe guten Aufschluss darüber geben, ob die Wasserbewegung durch die Strasse von Dover kanal- oder nordseewärts gerichtet ist.

Bruno Schulz.

W. Bein, H.-G. Hirsekorn und L. Möller. "Konstantenbestimmungen des Meerwassers und Ergebnisse über Wasserkörper." Veröff. Inst. f. Meeresk. N.F., Reihe A, H. 28. Berlin, 1935.

The Physikalisch-Technische Reichsanstalt and the Institut für Meereskunde, working together during the years 1928 to 1932, have made notable contributions to the study of sea water. Highly accurate density determinations by sinker weighings and dilatometer measurements, and improved indirect determinations of density by the measurement of optical, chemical, and electrical properties, are fully described and discussed in the paper under review.

A final section of the report in which Dr. Möller deals with the characteristics of the water of the Atlantic Ocean is reviewed elsewhere.

An opening survey of methods employed in the laboratory and at sea since 1893 for the direct and indirect determination of density is given by Dr. Möller. Further details of previous work are given by Dr. Bein in a section in which he deals with its inadequacy, and concludes that hydrostatic weighings are the easiest, quickest, and most accurate of the direct methods for the determination of density.

The main sinker weighings were carried out at air temperatures with a 200 ml. Jena 16^{III} glass plummet of mass 300 gm., which has been in use for 40 years, during which period its volume and mass have experienced a steady loss amounting in all to 0·002 ml. and 0·7 mg. respectively. These results are based on Thiesen's data for the density of distilled water, and it is therefore inferred that the isotopic content of the distilled water used from year to year has not varied significantly. An overall accuracy of 5×10^{-6} gm./ml. is assigned to this part of the work. Expansion data for sea water between 0° C. and 40° C. were derived from six 100 ml. dilatometers having narrow expansion tubes in which the position of the

liquid meniscus was determined to 0·04 mm., which corresponds to 0·001 ml. A control was obtained by further sinker weighings.

The main optical measurements were made by means of an interferometer due to Dr. Kösters, Hallwachs' method having been found inadequate largely owing to disturbances of refraction in the apparatus due to slight changes in the position of, and the forces acting on, the glass plates. In the Kösters apparatus, the Kösters prism splits a parallel beam of light into two portions which traverse paths similar to each other. One portion passes twice through about 4 cm. of distilled water and a plain glass plate, while the other twice traverses an equal linear distance in the sea water under test, and a compensator plate. The compensator plate has parallel faces and consists of two glass wedges movable relative to each other by means of a micrometer so as to vary the overall thickness of the plate. The two beams of light are finally recombined by the prism, and interference fringes are viewed in a telescope. The instrument is calibrated against fundamental density determinations so that the micrometer readings (with certain corrections which are given in detail) are convertible directly into density. The interferometer measurements agreed with direct density measurements to within 3×10^{-6} gm./ml.

On the basis of the fundamental density determinations and optical observations the following data are given.

I. Ratios of the volume of sea water at t° C., to its volume at 20° C., for samples of specific gravity $S_{17.5° C/17.5° C.}$ between 1·000 and 1·040 the temperature interval covered being 0° C. to 40° C. These ratios are set out to one part in a million.

II. Density (gm./ml.) between 0° C. and 40° C. of samples whose specific gravity $S_{17.5° C/17.5° C.}$ lies between 1·000 and 1·032. The densities are given to 1×10^{-6} gm./ml.

The new tables agree with the results of Forsch and Knudsen to the equivalent in density of one or two parts in 100,000. The discrepancies are largely systematic, and are ascribed chiefly to the fact that the earlier results were obtained with water from inner seas which has different chemical composition and thermal expansion from that of the ocean water used for the work under review.

The accuracy of the titration method was improved by the use of carefully designed apparatus and by attention to detail. A series of five burettes covering between them the whole range of chlorine content from zero upwards was evolved. Chloride values self-consistent to 0·001 $^0/_{00}$ by weight were obtained, and from the results, taken in conjunction with the results of Knudsen, Thompson, and Ruppin, it is concluded that for samples taken from the open seas the Dittmar constant at 17·5° C., i.e., the ratio

$$\frac{\text{Weight, in grammes, of chlorine in 1000 grammes of sea water}}{(\text{Specific gravity } S_{17.5° C/17.5° C.} - 1) \times 1000}$$

is 1·3805. Due allowance being made for the effect on the calculations of changes in accepted atomic weights, it is found that Knudsen's tables, when applied to water from the open sea, are more accurate than Knudsen himself reckoned.

The conductivity method, often used in America, has much to recommend it for use at sea. There are, however, many sources of error in the method, such as the liability to changes in the instruments and adsorption at the electrodes, which are gone into in detail. Full particulars of the apparatus

evolved and the precautions observed are given, together with tables showing the specific conductivity of sea water with an 800 cycle current, and its dependence on density and temperature. It is concluded that the indirect determination of density by the conductivity method as at present developed cannot be made more closely than 0·00001 gm./ml.

A concluding section gives the results of sinker, optical, electrical, and chemical measurements in the laboratory on samples taken from seas in various parts of the world. The density of each of thirty samples was determined either twice or three times by sinker weighings, and the maximum difference between any two results for a single sample was 9×10^{-6} gm./ml., the arithmetic mean of their differences being 3×10^{-6} gm./ml. The differences between the values of (specific gravity $S_{17.5^\circ C./17.5^\circ C.}$—1) × 1000 derived from the mean determined densities and those indirectly determined by the interferometer vary from -14×10^{-6} gm./ml. to $+22 \times 10^{-6}$ gm./ml. with an arithmetic mean of 7×10^{-6} gm./ml. Suggestions for improvements in the interferometer are given.

Corresponding figures for the results obtained by the conductivity method are as follows. The differences between the fundamental and the conductivity results vary from -34×10^{-6} gm./ml. to $+8 \times 10^{-6}$ gm./ml., and the arithmetic mean of the differences is 9×10^{-6} gm./ml.

The report on the chemical measurements takes the form of a further discussion of the Dittmar constant. This was shown to be independent of the age of the sample, but to vary considerably with the locality and the depth from which the sample was taken. The values agree on the whole with those of Thompson, due allowance being made for the different atomic weights employed in the calculations, but are about 0·0010 greater than those calculated from Knudsen's hydrographical tables.

Much excellent work has gone to this important report, which not only sets out very fully the work carried out, but also records and discusses the work of previous investigators. A criticism, at first sight perhaps pedantic, but really of considerable practical importance, is the misuse of the word "Dichte" for such functions as ($S_{17.5^\circ C./17.5^\circ C.}$—1) × 1000. Clarity demands that in work of this kind "Dichte" in German (or "density" in English) should be used only to denote mass per unit volume.

Further, the physical property of sea water with which the other constants are correlated is its density — mass per unit volume. The expression of this property in fundamental units, namely, grammes per millilitre, has much to recommend it in preference to "specific gravity" and derived functions of specific gravity such as ($S_{17.5^\circ C./17.5^\circ C.}$—1) × 1000, and ($S_{0^\circ C/4^\circ C}$—1) × 1000 commonly used in work on sea water.

P. H. B.

E. Gödecke. "Der Kalkgehalt im Oberflächenwasser der Unterelbe und Deutschen Bucht." Arch. Deutsch. Seewarte. Bd. 55, Nr. 1, S. 1—37, 27 Fig., 4 Anhangs-Taf. Hamburg, 1936.

Dr. Gödecke has investigated the calcium carbonate conditions in the mouth of the River Elbe and the adjacent parts of the North Sea, the "Deutsche Bucht." The work is based upon determinations of salinity and alkalinity in a great number of water samples collected on several cruises in the course of one year. The salinity determinations were about 2,500 in number and those of the alkalinity amounted to 2,149. The total

number of titrations, including preliminary work and control, was about 9,000.

The author starts by proposing the following definition: "The alkalinity is equal to the excess of bases over strong acids." This definition is, however, as old as the determination itself. It is to be regretted that the author, in the course of the work, does not keep to it, but gives yet another one, stating that the alkalinity in practice may be considered equal to the lime content. As the different ions in a solution are free and in no way bound to each other — a fact which the author points out himself — and as in sea water neither the concentration of the Ca-ions nor that of the CO_3-ions agrees with the alkalinity value, the second definition is obviously not correct. However, if solid $CaCO_3$ precipitates from the water or if such is dissolved, the value of the alkalinity will change by an equivalent amount. These very changes being the subject of the investigation, the determinations of the author nevertheless give the information which he is looking for.

The author uses chiefly the method of Wattenberg. The water being rich in suspended matter, it is filtered before the determination. The alkalinity values obtained on filtered and unfiltered water may differ considerably. The author is of the opinion that the difference indicates quantitatively the amount of suspended lime, organically or inorganically bound. It seems, however, doubtful whether calcium carbonate shells and skeletons really become completely dissolved in the course of an alkalinity determination.

In the area investigated conditions have been found to be rather complicated. The distribution of the lime content, i.e., the alkalinity, is closely connected with that of plankton organisms provided with a shell of calcium carbonate. In the areas Oberelbe and Unterelbe the lime content diminishes in spring and in the summer, while in the autumn and the beginning of the winter it is increased by dissolved or suspended material. The author is of the opinion that the water in the neighbourhood of Hamburg is being "delimed" from biological reasons. The water here being strongly polluted, considerable quantities of organic acids or bases may be formed, influencing the result of the alkalinity titration in one direction or another, for which reason it does not seem quite safe to draw conclusions as to changes in the lime content. The results of the author are, however, supported by the composition of the plankton in the water and by the lime content of the bottom muds. Thus in the area Oberelbe and Unterelbe a minimum in the lime content coincides with a maximum in the plankton production and *vice versa*.

Where fresh and salt water meet the author has found the maximum coagulation to take place at a salinity of 1 to 2 $^0/_{00}$. This so-called critical salinity agrees well with observations by others (Stina Gripenberg). The author has calculated equations giving the interdependence of salinity and alkalinity in different areas. For the entire area at the mouth of the Elbe the following relations were found in the summer of 1933: —

$$\text{unfiltered water } A_u = 1{\cdot}920 + 0{\cdot}0147\ S,$$
$$\text{filtered } \text{,,} \quad A_f = 1{\cdot}727 + 0{\cdot}0190\ S.$$

The general relation for the "Deutsche Bucht" was: —

$$A_u = 0{\cdot}06789\ S,$$
$$A_f = 0{\cdot}06677\ S.$$

In reality there are constant variations regionally and with time. Thus the author has established that there is no continual increase towards the

mainland, as has earlier been presumed, but that the suspended lime as well as the total lime content first increases, passing from the sea towards the river mouths, and then decreases again in the rivers proper. Regarding conditions in the separate areas and the explanations given thereof, the reader is referred to the original.

K. B.

H. Pettersson and **S. Landberg.** "Submarine Daylight." Göteborgs Kungl. Vet.- och Vitt.-Samh. Handl. 5 Föl., Ser. B, Bd. 3, No. 7, pp. 1—13, 5 Fig. Göteborg, 1934.

H. Pettersson. "A Transparency-Meter for Sea-Water." *Ibid.* No. 8, pp. 1—17, 4 Fig. Göteborg, 1934.

The oceanographer may desire to make photometric measurements under water for either of two distinct purposes. He may desire to know the intensity of the radiation of various wave-lengths (of which those in the visible spectrum are generally the most important) at various depths, or he may be especially interested in the opacity of the water, which gives a measure of the amount of suspended matter present, and may yield a useful clue as to its origin. If he is interested in both of these problems he can obtain a measure of the opacity from a comparison of the illuminations at different depths, and this course has hitherto been adopted by workers in the subject.

The first of the papers under review describes a simple form of submarine photometer using a Lange selenium cell of the rectifier type, the current being measured by means of a sensitive galvanometer. The apparatus evidently works well in the comparatively smooth water in which it was tested in the Baltic, and the vertical extinction coefficients obtained from the readings show a general similarity to those found under similar conditions by other workers. As no colour filters were used, and the cell possesses a considerable range of sensitivity, the variation in the colour of the light reaching it at different depths complicates the interpretation of the results.

The second paper describes an entirely new form of apparatus in which the reduction in a beam of artificial light due to absorption and scattering in a length of two metres of water is measured by means of a Lange cell. This direct measurement of the transparency of the water avoids several objectionable features inherent in the alternative method of deducing it from the ratio of two daylight measurements, and possesses the further advantage that the rapid variations in transparency with depth which occur under some conditions, can be readily observed. The absolute values of the extinctions so found do not, however, bear any simple relation to the vertical extinction coefficients for daylight, and the result depends, not only on the opacity of the water, but also on the exact design of the instrument and on the colour temperature of the lamp used as a source. It seems probable that instruments of this type will in future be used for studying variations in transparency, and an exact specification, capable of reproduction by other workers, is highly desirable.

H. H. P.

Per Ottestad. "On Antarctic Copepods from the 'Norvegia' Expedition." Sci. Res. Norwegian Antarctic Exped. No. 15. Oslo, 1936.

This is an account of the biology and distribution of four species of copepods, *Calanus acutus, Calanus propinquus, Rhincalanus gigas,* and *Metridia gerlachei,* taken during the circumpolar voyage of the "Norvegia" in 1930—31. These species were selected for detailed study as being the most plentiful in the area traversed. They have already been dealt with in publications by R u u d and M c I n t o s h, and the present paper amplifies the earlier accounts, by filling in, though only by a single line of stations, areas previously unexplored. Serial vertical hauls, most of them extending to a depth of 400 metres or more, have ensured a comprehensive sampling.

Three of the species mentioned, *Calanus acutus, Calanus propinquus,* and *Metridia gerlachei,* agree, according to the author's deductions from his observations, in having, in the Antarctic, a single spawning period which takes place shortly after the melting of the ice, the presence of a new brood having been noted in company with the spawning survivors of the previous year. The place of reproduction for all three species is to the south of the antarctic convergence, i.e., the junction between the antarctic and the sub-antarctic water. The production of the new brood depends, in the author's opinion, on the warming of the surface water to a positive temperature. It results from this that since this warming-up occurs at different times in different areas, specimens in all stages of development may be found at any time during the antarctic summer.

The fourth species, *Rhincalanus gigas,* showed no indication of a new brood on the antarctic stations but on one station north of the convergence and on another situated upon it there are clear signs of the presence of a summer brood distinct from the winter stock. It is inferred from this that spawning takes place in the sub-antarctic region and that the stock in the Antarctic is renewed by the drifting in from the north each year of some of the summer brood, probably by a sub-surface current, for the antarctic surface drift is mainly from the west with a northward component. This drift must bring in very considerable quantities to account for the high number of specimens found on some of the stations south of the convergence. It is probably significant that the young stages of *R. gigas* are not found most abundantly in the surface layers but occur with equal or greater frequency down to 300 metres. Whether a sufficient breeding stock remains north of the convergence or whether it is renewed by the drifting back of the adults by a return current is not yet apparent.

G. P. F.

G. L. Clarke. "The Diurnal Migration of Copepods in St. George's Harbor, Bermuda." Biol. Bull. Woods Hole, Mass., Vol. LXVII, No. 3, pp. 456—460. U. S. A., 1934.

The vertical distribution of two species of planktonic copepods *Calanopia americana* and *Acartia spinata* was studied in water 12·5 to 14 metres in depth in St. George's Harbor, Bermuda. Both species occurred at the surface and in the deep layers at night, but at sunrise they migrated to the bottom. While *Acartia spinata* was caught in fair numbers in the water layers close to the bottom in the daytime, the behaviour of *Calanopia americana* was rather unusual. The very large population of that species which was found at night disappeared almost entirely in the daytime from the water layers above the bottom. It was thought that these copepods may have actually burrowed into the soft mud on the bottom in the daytime. This

was confirmed by placing specimens in glass dishes with a layer of harbour mud on the bottom; the copepods buried themselves almost immediately. This is all the more remarkable in that the indications are that *Calanopia* is a truly pelagic form, and the possibility that other plankton animals may at certain times do likewise should be borne in mind.

F. S. R.

M. V. Lebour. "Notes on the Plymouth species of *Spirontocaris* (Crustacea)." Proc. Zool. Soc. London. Pt. 1, 1936, pp. 89—104, 7 Plates. London, 1936.

Four years ago Miss L e b o u r described the development of *Spirontocaris cranchii*, the only species of the genus known to occur at Plymouth. Further observation showed that there are two forms of *Spirontocaris* larva in the plankton which differ in the number of exopods on the legs, and these larvae were reared through a succession of post-larval moults until it became clear that there are two perfectly distinct adult species of *Spirontocaris*, one of which is described as a new species, *S. occulta*. Study of the literature shows that this new species has been seen before, but has been confused with *S. cranchii*, which it very closely resembles in outward form. Curiously enough Miss L e b o u r finds that *S. cranchii* has no mandible palp, although the presence of the palp is the main character which separates *Spirontocaris* from the allied genus *Thor*. She notes a correspondence between the habitat and the degree to which the palp is developed in different species of *Spirontocaris*, and discusses its value as a systematic feature.

Her description of the adults and larvae of the two species, with a comparison of the larval forms of the genera *Spirontocaris* and *Hippolyte*, and discussion of the epipodites in relation to the accepted gill formula, is a valuable contribution to the systematics of the Hippolytidae. Miss L e b o u r's work on *Caridion* and *Spirontocaris* shows the great importance of the study of the larval phase in the systematics of the Decapoda, and it is unfortunate that her opportunities for further contributions of this kind are so limited by the absence from the British fauna of genera such as *Thor* and other Hippolytidae.

R. G.

Å. Vedel Tåning. "On the Eggs and Young Stages of the Halibut." Medd. Komm. Danmarks Fisk.- og Havunders., Ser. Fisk., Bd. X. Nr. 4, pp. 1—23, 8 Fig. København, 1936.

Trotz der grossen Verbreitung des Heilbutts *(Hippoglossus hippoglossus* L.) und seiner wirtschaftlichen Bedeutung ist die Aufhellung seiner Lebensgewohnheiten bisher erheblichen Schwierigkeiten begegnet, und wie bei der Erforschung der fischereibiologischen Eigentümlichkeiten seines Verwandten, des pazifischen Heilbutts *(Hippoglossus stenolepis* P. Schmidt), so hat die Feststellung einiger wichtiger Tatsachen, den Laichvorgang betreffend, recht lange auf sich warten lassen.

Nach den früheren Bemühungen dänischer und norwegischer Forscher ist aber jetzt durch die Beobachtungen von Å. V e d e l T å n i n g, die in der vorliegenden Arbeit veröffentlicht werden, ein entscheidender Schritt vorwärts gemacht worden, und besonders sind wir über die Beschaffenheit der planktonischen Eier des Heilbutts jetzt völlig im klaren.

Nachdem G. R o l l e f s e n auf Grund einer im Aquarium zu Trondheim

erfolgreich durchgeführten künstlichen Befruchtung von Heilbutteiern in der Lage war, einen Bericht über seine Versuche nebst einer lückenlosen Reihe Abbildungen der embryonalen Entwicklungsstadien und der Larven bis zum Alter von 6 Tagen und 8·5 mm. Länge zu veröffentlichen (Kgl. Norske Vidensk. Selsk. Forh. VII, 7 p. 20—23, 1934), konnte Ä. Vedel Tåning gewisse von ihm in Tiefen von 200 bis 700 m. (über 1100 bis 2000 m. Gesamttiefe) zwischen Färöer und Island erbeutete bathypelagische Eier als vom Heilbutt stammend identifizieren.

Es ergibt sich hieraus, dass der Heilbutt zum Zwecke der Laichabgabe in diese recht erheblichen Tiefen abwandert.

Die Eier sind glashell mit ziemlich dickem Chorion und ohne Öltropfen, und ihr Durchmesser kann zu 3 bis 3·8 mm. angenommen werden, in Übereinstimmung mit älteren Angaben verschiedener Beobachter (z. B. E. W. L. Holt), die in der Lage waren, mehr oder weniger reife Ovarialeier zu messen. Besonders auffallend ist der sehr kleine perivitelline Raum, der das Ei auf den ersten Blick von dem Ei von *Drepanopsetta* unterscheidet, das trotz der viel geringeren Grösse des Fisches einen fast ebenso grossen Durchmesser hat (1·4 bis 3·5 mm.), den es aber seinem sehr grossen perivitellinen Raum verdankt. Bemerkenswert ist auch, dass das bathypelagische Ei des Schwarzen oder Grönland-Heilbutts *(Reinhardtius hippoglossoides* Walb.) nach den Feststellungen von Ad. S. Jensen mit 4 bis 4·5 mm. Durchmesser noch grösser ist als das Heilbuttei.

Im Anschluss an die schon von Johs. Schmidt veröffentlichten Beschreibungen und Abbildungen der planktonischen Larvenstadien und der Bodenstadien der 0-Gruppe konnte Ä. Vedel Tåning jetzt eine vollständige Übersicht über alle charakteristischen Larven- und Jungfischstadien mit einigen Abbildungen geben, die planktonischen Stadien von 13·5 mm. an aufwärts, die Bodenstadien von 47 mm. an aufwärts. Der Autor hebt hervor, dass er an den lebend frischen Heilbuttlarven von beiläufig 21 mm. Länge zahlreiche Erythrophoren beobachten konnte, deren Vorhandensein an ähnlichen planktonischen Stadien schon Johs. Schmidt festgestellt hatte, und die offenbar sehr charakteristisch sind. Eigentümlich ist diesen Stadien auch das Fehlen des Schwanzflossen-Pigments.

Nach den vorliegenden Beobachtungen kann angenommen werden, dass der Übergang vom pelagischen zum Leben auf dem Boden bei Längen von 35 bis 40 mm. stattfindet. Die Bodenstadien sind an der besonderen Form der Seitenlinie sowie an der Zahl ihrer Flossenstrahlen leicht kenntlich; ihre Pigmentierung ist lebhaft schwarz und kastanienbraun.

Im Hinblick auf die jetzt vermehrte Kenntnis der Verhältnisse stellt Tåning fest, dass die Laichzeit des Heilbutts im nördlichen Atlantik in die Monate März bis Mai fällt unter Bevorzugung des April. Als Laichgebiet kommt wahrscheinlich das warme (4° bis 7° C.) atlantische Wasser in und über Tiefen von 1000 m. und mehr in Betracht; doch ist es merkwürdig, dass eine künstliche Befruchtung der Eier und ihre Entwicklung bis zur Dottersacklarve im Aquarium möglich war.

Als Anhang zu seiner Arbeit gibt Tåning eine Übersicht über die in der Dänemark-Strasse, vorwiegend im kälteren Wasser der Grönlandseite, beobachteten pelagischen Entwicklungsstadien des Schwarzen Heilbutts *(Reinhardtius)* von 22 bis 48 mm. Länge.

[Unmittelbar nach der Arbeit von Tåning ist eine ausführliche Abhandlung über die frühe Lebensgeschichte des pazifischen Heilbutts erschienen (W. F. Thompson & R. van Cleve in Rep. Internat. Fisheries Commission Nr. 9. Seattle, 1936), die trotz der Übereinstimmung beider

Heilbuttarten in manchen Punkten und trotz der Unsicherheit der amerikanischen Tiefenangaben, deren Methodik von der europäischen wesentlich abweicht, erkennen lassen, dass fundamentale Unterschiede im biologischen Verhalten beider Formen bestehen. Die Eier des pazifischen Heilbutts sind offenbar *nicht* bathypelagisch; die meisten wurden in etwa 80 m. Tiefe ("with 250 m. of cable") gefangen, und zwar im Januar!]

E. Ehrenbaum.

A. Bowman, with the assistance of **Bennet B. Rae.** "Lemon Soles *(Pleuronectes microcephalus)*. Marking Experiments in Scottish Waters during the period 1919—1931." Fisheries, Scotland, Sci. Invest. 1935, No. I, pp. 1—42, 1 Fig., 6 Charts. Edinburgh, 1936.

Obgleich fast alle Arten der Gattung *Pleuronectes* wirtschaftlich eine grosse Rolle spielen, so ist doch ihre Lebensgeschichte nicht immer entsprechend dieser Bedeutung studiert worden, und erst in neuerer Zeit hat man sicht bemüht, die hier vorhandenen Lücken in unserer Kenntnis auszufüllen. Dies ist in weitgehendem Masse durch die schwedischen Untersuchungen an der Rotzunge *(Pleuronectes cynoglossus)* gelungen (vergl. *Journal du Conseil* X, 3, pp. 339 und 340) und jetzt auch durch die vorliegende Veröffentlichung der 12-jährigen Forschungsarbeit von A. Bowman über die Limande *(Pleuronectes microcephalus)*.

Die Ergebnisse dieser schottischen Untersuchungen beruhen hauptsächlich auf jahrelang fortgesetzten Markierungen, bei denen von 7799 Individuen 1015 Stück = 13 % wiedergefangen wurden. Besonders zahlreich waren die Wiederfänge in dem Gebiet östlich vom Moray Firth, und zwar erstreckten sie sich hauptsächlich auf die grösseren Fische (> 40 cm.), was wohl darauf zurückzuführen ist, dass die kleineren im Schleppnetz stärker beschädigt werden. Da die Limandenfischerei in der NW.-Nordsee hauptsächlich von schottischen Häfen aus betrieben wird, so ist es natürlich, dass in diesen die meisten Wiederfänge gelandet wurden, und zwar hauptsächlich während der Laichzeit im Sommer.

Die Männchen werden bei einer geringeren Körpergrösse laichreif als die Weibchen; sie fanden sich das ganze Jahr hindurch in reifem Zustand, wenn auch hauptsächlich in den Sommermonaten, reife Weibchen dagegen nur vom März bis Oktober und meist vom Mai bis August.

Verschiedene deutliche Laichplätze konnten in dem Gebiet östlich von Schottland festgestellt werden, namentlich einer östlich von Aberdeenshire. Es erwies sich, dass die Limanden zum Zwecke der Laichablage sich in den meisten Fällen der Küste genähert hatten; doch hatten die wiedergefangenen Fische in der Mehrzahl der Fälle (fast 80 %) die Aussetzungsstelle in einem Umkreis von 30 Ml. *nicht* verlassen und waren dort vereinzelt bis zu fast 10 Jahren verblieben.

Für diejenigen Exemplare, denen eine Abwanderung — zum Teil auf erhebliche Entfernung und mit einer Schnelligkeit von bis zu 2 Ml. per Tag — nachgewiesen werden konnte, liessen sich allgemein gültige Regeln hinsichtlich der Zeit und der Richtung nicht feststellen, da sich die einzelnen Individuen verschieden verhielten. Die Erfahrung zeigt, dass nach Verlauf von zwei Jahren seit der Markierung die Zahl der Wiederfänge sich stark verringerte, und dass nach 4 Jahren nur noch ganz wenig Wiederfänge eingeliefert wurden.

Ob die Limanden nach Erreichung der Geschlechtsreife alljährlich am Laichgeschäft teil nehmen, war bisher nicht festzustellen.

Einstweilen darf angenommen werden, dass die Limanden überall auf dem Nordseeplateau laichen, wo Beobachtungen gemacht wurden; doch müssten, wie der Autor selbst betont, zur Feststellung bevorzugter Laichplätze fortlaufend Untersuchungen über Ort, Zeit und Häufigkeit des Vorkommens von planktonischen Eiern und jugendlichen Larven der Limande angestellt werden.

E. Ehrenbaum.

G. A. Steven. "Migrations and Growth of the Thornback Ray *(Raia clavata* L.)." Journ. Mar. Biol. Assoc. Vol. XX, No. 3, pp. 605—614, 2 Fig. Plymouth, 1936.

This paper adds another chapter to the valuable work which is being carried out by Mr. Steven on the rays and skates of Devon and Cornwall, and records the results obtained from marking Thornback Rays with reference to their migrations and growth. Of the 614 individuals which were captured, marked, and then set free, 203 (or approximately 33 %) were recaptured after periods varying from 12 to 1,357 days. Of the recaptured fish, no less than 124 (61 %) were retaken on the exact spot where they were released, and 144 (71 %) had gone less than 5 miles from that spot; only 11 individuals had moved more than 20 miles and a single one had travelled more than 50 miles. Most of the fish marked were immature, so that it may be stated that during their growing period Thornbacks show no migratory movement, but merely a slow diffusion outwards in all directions. Mr. Steven has as yet few data concerning the adult fish, but suggests that they probably show a limited amount of migratory movement.

An interesting feature of these marking experiments is that of repeat captures. Ten fish were recaptured more than once, and one particular ray was caught by the "Salpa" no fewer than 4 times within a year after it had been marked, at intervals varying from 13 days to $4\frac{1}{2}$ months, each time in exactly the same place, and was finally caught again and killed by a commercial vessel 14 months after marking and still in the same place. Mr. Steven points out that these experiments indicate a high survival power on the part of immature Thornbacks, which will apparently withstand pretty severe treatment. He suggests that as a practical measure it would repay commercial trawlers to "take the shortest possible hauls which are consistent with fishing efficiency, and to return at once to the sea all rays which are too small to be marketable." Such action would lessen the danger of overfishing a particular ground and thus reducing the stock of fish, and should appeal to the intelligent fisherman, for, being practically non-migratory, the fish returned to the sea would grow up on the same ground, and he himself would reap the benefit of his action when they reached saleable size.

In the second part of the paper Mr. Steven analyses the data concerning the growth of the marked rays. He finds that the rate of growth is approximately the same in the two sexes, but that, whereas the males become adult when about 7 years old, the females do not reach sexual maturity for another 2 years or so.

J. R. Norman.

G. Gilson. "Recherches sur la Destruction du jeune poisson par la Pêche crevettière sur les Côtes de Belgique." Ann. Inst. d'Études Marit. Belgique. Mém. No. 3, p. 1—72. Lierre, 1935.

Die Arbeit Gilsons stellt eine Forsetzung seiner Untersuchungen über die belgische Küstenfischerei in den Jahren 1906—1926 dar, deren hauptsächliche Ergebnisse 1928 (Rapp. et Proc.-Verb. Vol. LI) veröffentlicht wurden. Inzwischen ist die Flotte der belgischen Garnelenfischer durchgehends motorisiert worden. Der Umfang der Vernichtung junger Nutzfische durch ihren Betrieb unter diesen ganz veränderten Verhältnissen ist nun durch neue Untersuchungen in den 16 Monaten von Mai 1932 bis August 1933 ermittelt worden.

Mit Bewunderung verfolgt der Leser die klare und vollständige Darstellung des Fischereibetriebs, der ökologischen und faunistischen Verhältnisse des Untersuchungsgebiets, der Untersuchungsmethoden mit ihren Vorzügen und Grenzen, und die Darlegung der ganzen verwickelten Frage der Schonung untermassiger Fische. Wir haben hier eine Schrift vor uns, die den Fernerstehenden mit der Eigenart fischereibiologischer Untersuchungen wirklich vertraut macht, und die dem, der auf dem gleichen Gebiet arbeitet, zur Klärung seiner Vorstellungen nützlich ist.

Dazu kommt die rein sachliche Bedeutung. Das Kernstück der Arbeit ist die Berechnung, wie viele kleine Nutzfische der belgischen Garnelenfischerei zum Opfer fallen. Die Grundlage dafür liefert die Untersuchung einer grossen Zahl gewerbsmässig gemachter Fänge des als typisch ausgewählten Kutters O. 1., die sich über die 16 Monate verteilen. Die Art, Zahl und Grösse der in jedem Fange erbeuteten Fische ist festgestellt worden. Es wird nun zunächst berechnet, wieviel Fische der Kutter in seinem ganzen Fangbetrieb gefangen hat, sodann die entsprechenden Zahlen für die gesamte Ostender Flotte. Für diese ergibt sich ein Fang von 87 Millionen Nutzfischen und 15 Millionen Stück nicht nutzbarer Arten. Für die wichtigsten Nutzfischarten werden errechnet: Klieschen 31 Millionen, Wittlinge 29 Millionen, Schollen 8, Seezungen 5, rote Knurrhähne 2, Flundern und Nagelrochen je 1 Million Stück. Berücksichtigt man ausser der Ostender Flotte auch die der kleinen Häfen, so kommt man auf eine Vernichtungsziffer von 200 Millionen Stück der genannten Arten in 16 Monaten.

Für die 7 wichtigsten Arten wird auch die Grössenzusammensetzung mitgeteilt. In jedem Falle ist die grosse Masse viel zu klein, um auf den Markt gebracht zu werden.

Gilson legt dann dar, dass jede Schonung untermassiger Fische dem Gesamtbestand marktfähiger Fische in der Nordsee zugute kommen muss. Je mehr Fische auf den Jungfischgründen geschont werden, desto mehr werden auch im Verlaufe ihrer Wanderungen auf die nahrungsreichen Aussengründe gelangen, wo ein gutes Wachstum stets möglich ist. Mit Recht nimmt Gilson Stellung gegen die Auffassung, als ob man schon heute die Nordsee bewirtschaften könne wie einen Fischteich, in dem man den Besatz mit Nachwuchs und die Ernährungsverhältnisse nach Belieben regelt. Wir haben nur die eine Möglichkeit, mit dem von der Natur erzeugten Nachwuchs so wirtschaftlich wie möglich umzugehen, d. h. kleine Fische zu schonen. Der Verf. weist darauf hin, dass eine Vergrösserung der Maschenweite der Garnelentrawls hierfür nützlich sein würde, dass aber erst geprüft werden muss, inwiefern der Garnelenfang dadurch beeinträchtigt wird. Er hält es dagegen für zweckmässig, die Anlandung kleiner Fische durch Mindestmasse für die Hauptarten zu verhindern. Die Fischer würden dadurch gezwungen, die kleinen Fische aus dem Fang auszusondern und

ins Meer zurückzusetzen, und würden es dann von selber vermeiden, an solchen Stellen zu fischen, wo Nutzfische besonders reichlich sind. Die infragekommenden Arten sind in der Mindestgrösse abgebildet, in der sie am Ostender Fischmarkt gelandet werden. Ferner ist berechnet, wieviel Fische geschont werden würden, wenn Mindestmasse in der Mindestmarktgrösse, von 18 cm. und von 24 cm. eingeführt würden. Bei den Mindestmassen von 18 und 24 cm. würde ein geringer Verlust für die Fischer dadurch entstehen, dass sie einige wenige kleine Fische nicht verkaufen dürften. Dafür würden aber 96 % bzw. 99 % der jetzt gefangenen Fische geschützt sein.

Bückmann.

G. Rollefsen. "The Spawning Zone in Cod Otoliths and Prognosis of Stock." Fiskeridirek. Skr. (Rep. Norwegian Fish. and Mar. Invest.) Vol. IV, No. 11. Bergen, 1935.

Mr. Rollefsen's work does two things of first importance. He successfully forecasts the size of skrei cod at least one year in advance. This is obviously of considerable practical interest. He also introduces into this sort of forecasting an estimate of the new recruits, a very elusive matter. Even in this difficult department he has achieved a real measure of success so far.

But these successes do not excuse a worker from the obligation to show others that his deductions are well founded, and that he has tested such assumptions as he can. For example, the author has not yet, in these three years and three papers, published any direct evidence that these special rings in the otolith are spawning rings. Instead he claims that the good fit of his forecasts affords "indirect proof." This will hardly do. There are various other factors in his calculations and the general good fit may, for all we know, be ascribed to the preponderating excellence of the data on proportionate strength of the year-groups. The good fit only shows that the spawning-ring factor has not introduced appreciable error, if any. A good fit is at best approximate and cannot show that the whole of a calculation is correct. If Mr. Rollefsen wants indirect evidence he will have to try something very much more complicated, but it seems much simpler to examine a few samples of mature and immature large cod, and prove the point directly.

Again, it is troublesome to find out for oneself that the histograms of Fig. 2 of this paper and Fig. 7 of his preceding one in the North-Eastern Area Report for 1934 do not agree exactly. It is only a small point, but we should have had it from the author, and with an explanation.

Advantages of Mr. Rollefsen's new method are: —

(1) A table arranged according to number of spawning rings and independently of age provides an estimate of mortality of spawners, which is comparatively independent of annual fluctuations (Fig. 5 of the preceding paper).

(2) Somehow — the reviewer has not found out exactly how — Mr. Rollefsen has produced ratios of the numbers of recruits at different ages in an age-group. So he can estimate later recruitment, once an age-group has appeared in the fishery.

These things are real and important advances and it is essential that the data and argument should be made plainer. Obviously Mr. Rollefsen is often near the fallacy of using percentages as absolutes. Once he clearly does it, when he gives a numerical estimate of an *absolute* increase in the

stock, from the *relatively* high number of 8-year-old recruits. This might be entirely due to paucity of other groups making up the per thousand table, although it is not very likely. The reviewer hopes that, if the expected increase takes place, Mr. Rollefsen will not claim that the agreement with his forecast affords indirect proof that there is no fallacy.

M. G.

S. Johnsen. "On the Variation of Fishes in Relation to Environment." Bergens Museums Årbok 1936, Naturvid. rekke, Nr. 4, pp. 1—26, 5 Fig. Bergen, 1936.

Diese Untersuchungen knüpfen an die Arbeiten von Johs. Schmidt über die ursächlichen Zusammenhänge zwischen der Variation gewisser numerischer Körpermerkmale und äusseren Einflüssen während der Entwicklung an. Johnsen geht von der auch bereits von anderen Seiten angestellten Erwägung aus, dass die Versuche Schmidts an *Zoarces* nicht eindeutig genug seien, weil es sich hierbei um einen lebend gebärenden Fisch handelt. Hier können also die äusseren Faktoren nie unmittelbar auf die Entwicklung einwirken. Johnsen hat deshalb als Untersuchungsobjekte *Spinachia* und *Gobius* gewählt, weil beide festliegende Eier haben und weil die Jungfische wahrscheinlich nicht sehr weit von ihren Geburtsplätzen abgetrieben werden und auch die erwachsenen Fische keine weiten Wanderungen unternehmen. Im übrigen ist ihr Lebenszyklus nur kurz. So werden hier gewisse Unsicherheiten ausgeschaltet, die bei anderen Fischen störend wirken. Es wird zunächst festgestellt, dass bei *G. flavescens* sich die geringeren Wirbelzahlen mehr bei den kleineren Tieren häufen, die höheren dagegen bei den grösseren. Bei der einen Darstellung, die sich auf eine einzelne Probe vom Osund bezieht, ist der Beweis zwar nicht ganz überzeugend, aber aus einer zweiten Darstellung, in welcher die mittlere Länge der Fische mit bestimmten Wirbelzahlen angegeben wird, zeigt sich bei allen verglichenen Plätzen ganz deutlich, dass die durchschnittliche Körperlänge bei den Individuen mit höherer Wirbelzahl grösser ist als bei den mit geringerer Wirbelzahl.

Nach kurzen Angaben über die drei untersuchten Arten *(G. flavescens, G. minutus, Spinachia spinachia)* geht Johnsen dann zur Erörterung der hier behandelten Frage über. Vor allen Dingen waren es Salzgehalt und Temperatur, die als bestimmende Aussenfaktoren in erster Linie und fast ausschliesslich berücksichtigt wurden. Ein endgültiges Ergebnis ist bisher nicht erzielt, trotz einer Allgemeinregel sind immer einzelne Ausnahmen festgestellt. Mit Recht hebt Johnsen hervor, dass nur dann ein eindeutiges Ergebnis erwartet werden kann, wenn eine wirklich genaue Kenntnis der örtlich gegebenen Aussenfaktoren vorliegt. Ein Vergleich des Jahresmittels der Oberflächentemperatur mit der mittleren Wirbelzahl, wie er von Schmidt durchgeführt ist, gibt nur oberflächliche Anhaltspunkte für die tatsächlich vorhandenen örtlichen Bedingungen. Weiter betont Johnsen mit vollem Recht, dass selbst dann, wenn die Temperatur, unter der die Entwicklung erfolgt ist, genau bekannt ist und reine Proben vorliegen, keine Allgemeinregel ohne Ausnahme erwartet werden kann, weil die Umwelt ein Komplex verschiedener Faktoren ist, aus dem man nicht einen Faktor herausnehmen kann, um ihn zu den körperlichen Merkmalen in Beziehung zu setzen. Er betont, dass nichts damit gewonnen wäre, wenn man ein verwickeltes Problem so behandelt, als wäre es ganz einfach. Für eindeutige Versuche muss eine unbedingt notwendige Voraussetzung sein, dass die formbestimmenden Faktoren bekannt sind und dass immer nur einer dieser

Faktoren geändert wird, während die anderen konstant bleiben müssen. Ausserdem müssen die Objekte in den Versuchsreihen gleichartig sein.

Johnsen wendet sich dann einem der von Schmidt an der Meerforelle durchgeführten Versuche zu. Das Ergebnis dieses Versuches war, dass die niedrigste Durchschnittszahl der Wirbel bei der mittleren der drei angewandten Temperaturen erreicht wurde. Diese mittlere Temperatur lag etwa um 4° C. Bei dieser Temperatur hat aber das Süsswasser sein grösstes spezifisches Gewicht. Es hat sich aber weiter aus den hier angeführten Versuchen von Schmidt ergeben, dass bei praktisch gleicher Temperatur sehr verschiedene Durchschnittswerte bei den Wirbeln herauskommen. Johnsen weist nun darauf hin, dass der Sauerstoffgehalt bei den drei Parallelversuchen verschieden gewesen sein muss. Und daraus muss geschlossen werden, dass ein hoher Sauerstoffgehalt die Entwicklung einer geringeren Wirbelzahl zur Folge hat. Das spezifische Gewicht (die Dichte) des Seewassers ist nun hauptsächlich vom Salzgehalt abhängig, aber auch von der Temperatur. Das spezifische Gewicht der Fischeier ist zur Laichzeit noch nicht endgültig bestimmt, sondern es wird verringert oder vergrössert, je nachdem ob die Eier in Wasser von höherem oder geringerem Salzgehalt abgelegt werden. Wenn man die einzelnen Faktoren (Temperatur, Dichte und Sauerstoff) berücksichtigt, so findet man, dass hohe Werte bei den Faktoren geringeren Werten bei der Wirbelzahl entsprechen. Mag diese Regel auch wohl im allgemeinen Gültigkeit haben, so werden die Verhältnisse durch die verschiedene Kombination der Faktoren in der Natur doch verwickelter und unübersichtlicher. Wenn hier ausserdem als Regel angegeben wird, dass bei geringerer Dichte des Wassers eine höhere Wirbelzahl erzeugt wird, eine geringere Dichte aber andererseits von geringerem Salzgehalt mitbestimmt wird, so entspricht doch diesem im allgemeinen eine geringere Wirbelzahl. Allerdings kann hier wieder ein anderer Faktor im entgegengesetzten Sinne wirken. Es ergibt sich aus allen hier von Johnsen angestellten Erwägungen, dass die Faktorenverhältnisse in der Natur wesentlich verwickelter und unübersichtlicher sind, als es bisher bei der Behandlung der Frage nach der Wirkung der Aussenfaktoren im allgemeinen berücksichtigt wurde.

Die Wirksamkeit der Aussenfaktoren ist in hohem Masse abhängig von der Entwicklungsdauer, sowohl der Eier wie der Larven. Eine kurze Entwicklung hat eine geringe, eine lange Entwicklung eine hohe Wirbelzahl zur Folge. Für die Strahlen der Vertikalflossen gilt im allgemeinen auch die "Süd-Nordregel", aber es besteht keine feste Beziehung zwischen der Strahlenzahl der Flossen und der Wirbelzahl. Die Strahlenzahl der Vertikalflossen ist jedoch abhängig von der Entwicklungsdauer. Wie bei den Wirbeln, so stellt Johnsen auch bei den Vertikalflossen fest, dass innerhalb der Jahresklassen die grösseren Individuen eine höhere Strahlenzahl aufweisen als die kleineren. Wenn aber vorausgesetzt wird, dass die grösseren Tiere früher geboren sind als die kleineren, so ist dagegen einzuwenden, dass das individuelle Wachstum auch unter den Fischen sehr verschieden ist. Aus der Grösse ist nicht unbedingt auf das Alter zu schliessen. Die Schwankungen in der Strahlenzahl der Brustflossen sind im allgemeinen umgekehrt wie bei den Wirbeln. Die Tatsache, dass die niedrigste Zahl am weitesten nördlich gefunden wird, scheint der Theorie zu widersprechen, dass eine Beziehung zwischen Zahl und Entwicklungsdauer besteht. Johnsen erklärt diesen Widerspruch damit, dass im Süden die Fortpflanzung bei *Gobius* früher beginnt als im Norden. Bei *Spinachia* zeigen die Strahlen der Brustflossen eine sehr geringe Variation. Die Flossenstrahlen sind alle

von gleicher Länge und Stärke. Es fehlen hier kleine, schwach ausgebildete Strahlen, wie sie in den Brustflossen anderer Fische zu finden sind.

Die vorliegende Arbeit Johnsens, die nur eine vorläufige Veröffentlichung darstellt, ist der grössten Beachtung wert und gibt manche Anregung, um einzelne Fragen dieses Problems weiter zu verfolgen.

Schmakenbeck.

W. Erdmann. "Untersuchungen über die Lebensgeschichte der Auster. Nr. 5. Über die Entwicklung und die Anatomie der ansatzreifen Larve von *Ostrea edulis* mit Bemerkungen über die Lebensgeschichte der Auster." Wiss. Meeresunters. N.F., Abt. Helgoland, Bd. XIX, Abh. Nr. 6, S. 1—25, 8 Taf., 5 Abb. Kiel u. Leipzig, 1934.

In spite of the numerous papers dealing with the biology of the Common Oyster we have hitherto had very little exact and detailed knowledge of the ontogenetic development of the oyster. This want has largely been filled by the above-mentioned investigation by Dr. Erdmann, which is the fifth number in the valuable series of oyster investigations made at Heligoland under the leadership of Dr. Hagmeier. Most workers who have been engaged on oyster investigations in the last decade have dealt with problems of ecology (the relations between temperature, food and other external conditions, and the fluctuations of the stock), and during these investigations the want of a good description of the different larval stages has been very much felt. In the paper by Dr. Erdmann the different stages of the oyster larvae from the beginning of the pelagie stage to the moment of spatfall are thoroughly described and very well illustrated in three text figures on which the position of the different organs can be easily found. Further, a complete series of microscopic sections of the full-grown larva is shown on several plates. Besides the description mentioned of the different organs of the larval stages the author gives a valuable comparison of his results with those of the few earlier investigations of the larval development of the Lamellibranchiata (Hatchek, Meisenheimer, the old description of the oyster larvae by Horst etc.). On the basis of this comparison the author has been able to correct the previous investigators on several points. In addition to the above-mentioned morphological results, which are the essentials, the author sets forth some observations concerning the biology of the oyster in which he corroborates those of previus investigators (e.g., concerning the period in which the larva remains in the mantle cavity of the mother animal). The reviewer must point out that Dr. Erdmann is incorrect when he places the reviewer among those who advocate a lunar periodicity in the spawning of the oyster. On the contrary, in the paper referred to the reviewer reaches the opposite conclusion. On the whole, the paper by Dr. Erdmann will be a very valuable help to oyster investigations in the future.

R. Spärck.

M. Ian Crichton. "Scale-Absorption in Salmon and Sea Trout." Fisheries, Scotland, Salmon Fish., 1935. No. IV. Edinburgh, 1935.

This publication of the Fishery Board for Scotland, being one of the latest of the series of papers relating to salmon biology, deals with some original investigations concerning the phenomenon of scale absorption.

The histological features of the process are illustrated by photographic reproductions of longitudinal sections through the scale tissue. Absorption

is shown as taking place at the periphery of the scale, the hyalodentine layer of the scale plate undergoing attrition at a greater rate and to a greater extent than the underlying fibrous layer. Normally, before absorption has started, the hyalodentine layer extends beyond the fibrous layer; but early in the process of absorption this order is reversed. Associated phenomena are irregularity in the outline of the covering epidermis, vacuolation of the epidermal cells suggesting degeneration, and massing round the scale margin of cells which appear to be identical with the scleroblasts responsible for the growth of the scale but for the time being phagocytic in function.

The correctness of the term "absorption" is here corroborated, and justification is furnished for definitely discarding as fallacious the assumption that the scale is subjected to a process of erosion, as such.

According to the author's observation, the epidermis covering the scale, even when the latter has been almost entirely absorbed, remains in being, though some of it (having become superfluous) may be shed as the scale contracts during the process of absorption. This disposes of the likelihood of mechanical factors operating from outside which is implied by the term erosion.

There is little room left for doubt that absorption is due to some physiological change which begins as soon as the fish ceases feeding and starts on its journey to the spawning grounds. The precise nature of this physiological change, however, remains undisclosed, though it seems reasonable to suppose that the demands of the developing genitalia furnish the explanation, in part, at all events.

The author discusses in a tentative way the suggestion that scale absorption has some connexion with the release, for the utilization of the ripening gonads, of chemical constituents (e.g., calcium) contained in the scale, but evidently hesitates to accept the idea without reservation, in view of the fact that scale absorption continues after the fish has completed the act of spawning, and until feeding is resumed.

Cessation of feeding is evidently the determining factor which initiates the process of scale absorption and the process continues throughout the period of food abstention. That seems to be, at the moment, the sum total of knowledge on the matter. And the reason why scale absorption is more marked in the males than in the females has yet to be explained.

T. E. P.-T.

H. Blegvad. "An Epidemic Disease of the Eel-Grass *(Zostera marina* L.)." Rep. Danish Biol. Stat. XXXIX, 1934. pp. 1—8, 1 Fig. Copenhagen, 1935.

This paper gives a brief account of the plant, followed by a fairly detailed history of the disease up till the summer of 1933.

Zostera marina, one of the few flowering plants found in the sea, has an extensive distribution in the Atlantic, and forms vast beds on the coast of Denmark in comparatively sheltered places where the bottom is fairly soft. In such places it grows down to a depth of about 11 metres and shelters a rich fauna of Crustacea and small fish, including the young of many fish of economic importance. The dead leaves, when they break off, float out to sea and form an important source of food for deeper water animals in places where other plant detritus is absent. The leaves are also collected and used in several industries. Consequently the disease, which was noticed in Portugal, France, and Holland in 1932 and which first caused the blackening of the leaves and ultimately the nearly entire

destruction of the plant, might easily have far-reaching effects. In Denmark enquiries about it were made by the author in 1933 when the first signs were observed in the Limfjord. Replies from fishery assistants, which are given in detail, showed that there was extensive dying-out in the northern part of the country, and there was reason to believe that it would soon become general. The broad-leaved form of the plant growing in deeper water was killed, while the shallow water form remained green. The author states that the mycelium of a fungus has been isolated from the diseased plant by H. E. Petersen, and that this has been found to stand a salinity of more than 5 % in culture. The fungus has not as yet been proved to cause the disease, but *Z. nana* Roth. is free from disease and does not appear to have the fungus.

A number of reports by workers in other countries, some of them previously unpublished, are summarized. Dina Spierenburg (Holland) states that the disease was bad in 1932 and expresses doubt about the bacterium found by Fischer-Piette, Heim, and Lami being the cause of the disease. Reports from America by Lewis, Huntsman, and Cottam show that the disease probably started in Virginia in 1930 and spread northward to Cape Breton and Northumberland Strait in 1931. On this evidence it is suggested that the disease originated in America and spread to Europe in the space of one or two years. Reports from Allen and Cotton recording the disease from various places on the south coast of England, from Bjerkan for the south-west coast of Norway, and from Molander and Lönnberg for Sweden, are also given.

The damage caused by the disease is hard to estimate, though the failure of the supply of leaves for insulating and upholstering has caused great loss in Holland. The failure of the Danish prawn fishery is reported in June 1933 but it is not known yet what effect the lack of *Zostera* detritus will have on the small bottom-living animals in deeper water.

T. G. Tutin.

H. E. Petersen. "Preliminary Report on the Disease of the Eel-Grass *(Zostera marina* L.)." Rep. Danish Biol. Stat. XL, 1935, pp. 3—8, 4 Fig. Copenhagen, 1935.

This interesting paper gives an account of a fungus found on *Zostera*, and discusses its relation to the disease from which the plant has been suffering. The disease appears as a wasting of tissue in the rhizome, leaves, and flowering stems, the roots apparently escaping. The first sign of disease is the appearance on the leaves of brownish or greyish spots which become darker in colour and spread till the leaf becomes detached and sinks. The mycelium of a fungus was found by the author in all the diseased parts of the plant in July 1933, and an earlier report by E. S. Dowding from the Laboratory of Plant Pathology of Ottawa stated that a mycelium had also been found in one piece of rhizome from Canadian waters. Further investigation confirmed the constant association of the fungus and the disease, and this was later corroborated by Miss Mounce, who found an identical fungus in Canadian material. This fungus was described by Miss Mounce and W. W. Diehl as *Ophiobolus halimus*. C. E. Renn at Woods Hole found a *Labyrinthula* constantly associated with the diseased condition in American waters, and the same organism was seen by the author in Danish material. Renn considers this to be the organism responsible and stated *(Nature,* Vol. 134, p. 416) "Further, we have been unable to observe the *Ophiobolus*-like fungus reported by other investigators

as commonly occurring on the rhizomes and leaves of diseased plants." However, the presence of the fungus was demonstrated in material sent by R e n n to the author, and it has also been found in most parts of the British Isles, so there can be little doubt that it is at least partly responsible. The perithecia are formed chiefly on the rhizome, but the ascospores do not survive very long and can therefore be of small importance in the spread of the disease. The carriage by sea of infected portions of the plant, which later produce spores, or infect fresh host plants by contact, seems the most likely method of transport. The spores are produced chiefly in autumn, those earlier produced being more viable than the later ones. They are long and threadlike and readily adhere to the plant, attacking chiefly the outer leaves and ends of the leaves. The hyphae put out by the germinating spores penetrate the epidermis and spread gradually through the tissues, eventually destroying the cells and preventing assimilation. The resulting defoliation seems to act as a stimulus to flowering in the more vigorous shoots, and seed is ripened normally. The fungus has been grown in pure culture on sea-water agar with *Zostera* extract added. All *Zostera* individuals are not equally affected by the disease. This may be due merely to bigger food reserves giving a greater power of resistance in some cases, or to the occurrence of genetically distinct races. Some of the narrow-leaved forms are attacked while others are immune. The former are probably phenotypes and the latter genotypes of the broad-leaved plant. A detailed report on the material examined (from 31 stations) is given and in conclusion it is suggested that recovery will probably occur either owing to the decrease in virulence of the parasite, or the increase in the number of immune individuals.

T. G. Tutin.

G. A. Steven. "Seals *(Halichoerus grypus)* of Cornwall Coasts." Journ. Mar. Biol. Assoc. N.S., Vol. XX, No. 3, pp. 493—506, 6 Fig. Plymouth, 1936.

For some years complaints have been made by the fishermen of Cornwall that seals have damaged the coastal fisheries, first by dispersing shoals of mullet, which on occasion yielded valuable catches, and second by paying attention to the drift-nets and actually removing from them herrings which had been enmeshed. The recent development of such damage was said to be due to the increase of the seal population, which was stated by the Cornwall Sea Fisheries Committee to number about two thousand, and upon these statements a drastic reduction of the number of seals was urged.

Before legislative or other steps could be taken to meet the demands of the fishermen, it was desirable that precise information should be collected regarding the seal population of Cornwall, and a survey with this end in view has been made by Mr. G. A. S t e v e n and is described in this paper. The results, which were attained with considerable difficulty, since many of the caves could be entered only by swimming, give the precise information which was required.

In the first place, doubt about the identity of the seals is set at rest, for only individuals of the Grey Seal *(Halichoerus grypus)* were seen. The Common or Brown Seal *(Phoca vitulina)* may be regarded for practical purposes as absent from the area.

In the second place, the habits of the seals differ from those of most of the Scottish representatives of the species in that they dwell all the year

round and breed in caves; although some caves which do not offer breeding places are nevertheless visited habitually by considerable numbers of seals.

In the third place, the survey has revealed the seal population on the north coast of Cornwall as numbering not less than three hundred and probably not more than five hundred individuals. For the south coast no estimate is given, but there the number "is certainly very small." The survey was carried out in 1935 from August 7th to 20th, before the breeding season had commenced, and it is possible that at this date the full population of the area had not concentrated in the breeding localities. Certainly in the great Scottish breeding areas the full population could not be estimated with accuracy from shore counts so long before the breeding congregation takes place, since many of the seals appear to spend their time out at sea. But the different habits of the Cornish seals render comparison difficult, and Mr. S t e v e n's estimate must be taken as the first reliable count, and the only count upon which argument for a reasonable reduction of the seal population of Cornwall can be based.

James Ritchie.

Current Bibliography.

Prepared by the Editor with the assistance of Miss Thursby-Pelham.

NOTE. The scope of the Bibliography is limited in the main to the area covered by the Council's activities, but there are included papers of general interest relating to other areas in the North Temperate and Arctic regions and exceptionally elsewhere. Limnological references are not as a rule given, but papers relating to brackish waters and to salmon and freshwater fish studied by the Council are included.

The classification of entries follows in a general way that adopted in Dr. Allen's Selected Bibliography published in Vol. I, Nos. 1 and 2 of the Journal, and since reprinted (Price, 1 Kr.).

Subscribers and those on the distribution list will receive regularly upon application to the Administrative Secretary copies of the Bibliography printed on one side of the page only, for use in making up card indices.

The Editor will be glad to be advised of emendations and additions to the Bibliography.

Physical and Biological Conditions in the Sea.

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